HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
U S ARMY

TECHNICAL REPORT
EP-91

Canal Zone Analogs II

ANALOGS OF CANAL ZONE CLIMATE IN INDIA AND SOUTHEAST ASIA

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION
NATICK, MASSACHUSETTS

JUNE 1958

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

Major General Andrew T. McNamara
The Quartermaster General
Washington 25, D. C.

Dear General McNamara:

This report, "Analogs of Canal Zone Climate in India and Southeast Asia," is the second of a series of studies comparing the climates of tropical areas throughout the world with the climate of the Canal Zone. The report presents information for military planners and test personnel concerning the degree to which the climates of Balboa Heights and Cristobal in the Canal Zone resemble those of India and Southeast Asia, and thus suggests the applicability to other regions of the results of equipment performance tested in the Canal Zone.

Sincerely yours,

C. G. Calloway

C. G. CALLOWAY
Major General, USA
Commanding

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EP-91

HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

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ANALOGS OF CANAL ZONE CLIMATE IN INDIA AND SOUTHEAST ASIA

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Prepared for the Environmental Analogs Project (8-97-10-004)
US Army Corps of Engineers, Waterways Experiment Station
Vicksburg, Mississippi

Project Reference:
7-83-01-005

June 1958

FOREWORD

A successful research, development, or training program requires a knowledge of the degree of environmental representativeness of test sites and training areas. The Quartermaster Corps, at the request of the Corps of Engineers, Waterways Experiment Station, under a directive from the U. S. Army General Staff, is developing a generalized, comparative, climatic picture of the wet tropics throughout the world by a series of tropical analog studies. The series parallels another already completed, which presented comparisons between Yuma, Arizona, and the various desert regions of the Northern Hemisphere.

This is the second report of the tropical series. It compares the Canal Zone climate with that of India and Southeast Asia, and by so doing provides a climatic reference for military planners and test personnel.

AUSTIN HENSCHEL, Ph.D.
Chief
Environmental Protection Research Division

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ABSTRACT

India and Southeast Asia are more variable in temperature and more seasonal in precipitation than the Canal Zone. North of 20° N latitude in the coldest month all stations are cooler than those in the Canal Zone. This is also true of most stations between 15° and 20° N. South of 15° N, large lowland areas are analogous for mean temperature of the coldest month. Except where special conditions prevail (cloudy Bengal, the eastern piedmont of the Himalayas, and the Arabian Sea coast), lowland stations north of 15° N are too warm for analogy in the warmest month, which is usually May, just before the rainy season. Temperatures are more moderate with the onset of the summer monsoon later in the year.

Nearly all of the area is analogous for precipitation amounts in the wettest month and during most of the summer monsoon season. Relative humidity is low in the driest month over most of the area, and high during the rainy season. Analogy for windiness and cloudiness of the wettest month is extensive. Because temperatures are moderate during the summer monsoon, multiple analogy with the Canal Zone is extensive at that time.

Year-round multiple analogy is limited to the southern part of the area. Areas of such analogy with Balboa Heights (on the Pacific side of the Canal Zone), which has well-marked seasons, are in Ceylon, southernmost India, Malaya, Laos, South Viet Nam, and Cambodia. Year-round composite analogy to Cristobal occurs only in Malaya. Areas of analogy are given in 14 maps; the last 2 maps show the distribution of multiple analogy.

ANALOGS OF CANAL ZONE CLIMATE IN INDIA AND SOUTHEAST ASIA

1. Purpose and scope

This report is the second of a series comparing the climate of tropical regions with that of Cristobal and Balboa Heights, Canal Zone. These two stations were selected to represent the climates of the Atlantic and Pacific portions of the Canal Zone, respectively. The environment of Cristobal is described in a previous report (Wiley and others, 1955).

No attempt has been made to provide a regional climatology of India and Southeast Asia. Instead, the method has been to select certain climatic elements that are considered particularly significant and, for each of these, to map the areas within the region considered closely analogous to either Balboa Heights or Cristobal. Some of the information presented on these maps of single climatic elements has been consolidated into two composite maps, one for each of the two Canal Zone stations, showing areas where there is a coincidence of analogy for several climatic elements.

2. Delimitation and geography of India and Southeast Asia

a. Topography

The area covered in this report includes India, Pakistan, Ceylon, and the mainland of Southeast Asia south of the Himalayas and the Chinese border, and north of 5° 31' N latitude. Indonesia and the southern part of Malaya will be covered in the seventh report of this series.

India* and Pakistan form a broad region which can be divided into two topographically distinct parts, Peninsular India and the Indo-Gangetic Lowland, the latter separating Peninsular India from the Himalayas and other high northern ranges. The northern ranges form a third topographic subdivision of the Indian region which is not tropical and is not treated here. Within the northern ranges there are small areas that are analogous to the Canal Zone for one or more of the climatic elements discussed in this report, but such areas are scattered and unrepresentative of any part of the mountain subregion. Peninsular India has fairly continuous narrow plains along both its eastern and western coasts. Inland from the western coast rise the Western Ghats, a range which forms a 3,000-foot barrier along most of that coast. From the crest of the Ghats, the interior uplands of the peninsula decline gradually toward the eastern coastal plain. They form a complex of hilly plateaus and low ranges, the Deccan Plateau and similar uplands, among which broad river valleys form extensions of the coastal and Gangetic Lowlands.

*Topographic regions underlined on these pages are identified in Figure 2.

The Indo-Gangetic lowland has very little relief. Along the western margin of the study area, the lowlands are mostly desert or semi-desert, either undrained or forming vast alluvial plains graded by the shifting of the Indus River and its tributaries. The Ganges Valley, in the center of the lowland, is formed of flood plains separated by areas of older, slightly uplifted flood plain. Scattered outlying hills extending north from Peninsular India partly separate the Ganges and Indus lowlands. The Ganges trough is continued eastward by the Brahmaputra Valley, floored by the flood plain of the braided Brahmaputra River and by the alluvial fans of its tributaries. In Bengal the Brahmaputra River merges with the Ganges River, turns southward, and forms a broad network of distributaries. The islands within the distributary net are formed from flood plains upstream, and are brackish mangrove swamps, the Sunderbans, near the sea.

Ceylon has a central upland similar to the Western Ghats in height and relief. The greater part of the island is coastal lowland.

Southeast Asia, in this report, includes Burma, Thailand, Indochina*, and the part of Malaya which lies north of 5° 30' N latitude. The boundary between this region and India is formed by the Assam-Burma Hills, of which the Khasi Hills are a western extension into India. The Assam-Burma Hills are a fairly high and rugged range of mountains which reach 8,000 or more feet in a number of places. The range effectively shelters the central and upper Irrawaddy Lowland, which lies just east of it, from the summer monsoon. The Shan-Laos Upland, a dissected plateau region of moderate elevation, extends from the Irrawaddy Lowland almost to the South China Sea, from which it is separated by the relatively small Tonkin Lowland.

An extension of the Shan-Laos Upland runs south along the coast of the South China Sea, forming the Annam Highlands, a range which reaches 10,000 feet at one peak. A less mountainous range extends from the Shan-Laos Upland southward along the coast of the Bay of Bengal, forming the upper Malay Peninsula. Between these two ranges, cut off from the northern Gulf of Siam by a narrow belt of hills, is the broadest plains area in Southeast Asia, the Menam-Mekong Lowland.

b. Major climatic controls

The regions discussed in this report are all tropical or subtropical and are strongly dominated by the Asiatic monsoon system. The summer monsoon, the principal rain-bearing wind of the area, is warm and has relatively little temperature variation. It first comes inland as a southwest wind across the Western Ghats and Ceylon, and maintains the same direction in the Ganges Valley and across Southeast Asia.

*Although the term "Indochina" has only regional significance today, it is used in this report to designate collectively the countries of Laos, Cambodia, and North and South Viet Nam.

Monsoon precipitation is particularly heavy on the windward faces of the Western Ghats, the Burmese coastal ranges, the Assam Hills, and the south slopes of the Eastern Himalayas during the summer. Cherrapunji, on the southern face of the Khasi Hills in Assam, is one of the rainiest stations in the world. The rest of the study area also receives much of its rain from the summer monsoon, but the total amount, heavy in Bengal, declines steadily northward in the Ganges Valley. Because it is in the lee of the Western Ghats, the interior of Peninsular India gets scant, unreliable rains. The central Irrawaddy Lowland is another dry area, particularly in the immediate lee of the Assam-Burma Hills. The Shan-Laos Upland, a sheltered interior region, also has relatively little rainfall.

The winter monsoon is the reverse of the summer monsoon both in its direction and in its climatic effects prior to passing over the sea. Until it is modified by passing over the sea, it remains a dry, cool wind. The periods of change between winter and summer monsoon during the spring and in the fall, are times of heavy precipitation. The modified winter monsoon also brings rain to the southern shores of the Gulfs of Tonkin and Siam.

The subtropical or northern parts of the study area have their highest temperatures in spring, usually in May, between the end of the winter monsoon period and the onset of the summer monsoon. These subtropical spring temperatures are characteristically somewhat higher than warm season temperatures in the tropics. During winter, the subtropical region is cool, though no station south of the Himalayas has a really cold winter. Winter cyclonic storms along the southern flank of the Himalayas bring considerable precipitation to the eastern area of Pakistan and northwestern India.

3. Climatic summary of the Canal Zone

The Pacific portion of the Canal Zone, represented by Balboa Heights, has a moderately humid tropical climate with a four-month dry season (Fig. 1). The difference in mean monthly temperatures of the warmest and coldest months is only 2F°, and the range from the highest mean daily maximum (March and April, 90°F) to the lowest mean daily minimum (February, 71°F) is only 19F°. Precipitation, averaging 70 inches annually, is markedly seasonal. Two months, February and March, have less than 1 inch of rainfall, and five months have more than 8 inches. The dry season begins in December and ends in April. Rainfall in each of the remaining months is more than 7 inches; October and November both have more than 10 inches. Relative humidity is high from June through November. Cloudiness is at a maximum from May through November, coinciding with the wet season; sky coverage averages about 8 tenths at Balboa Heights at that season. Wind speed, however, is greatest during the dry season; winds average 9 to 10 mph at Balboa Heights from January through

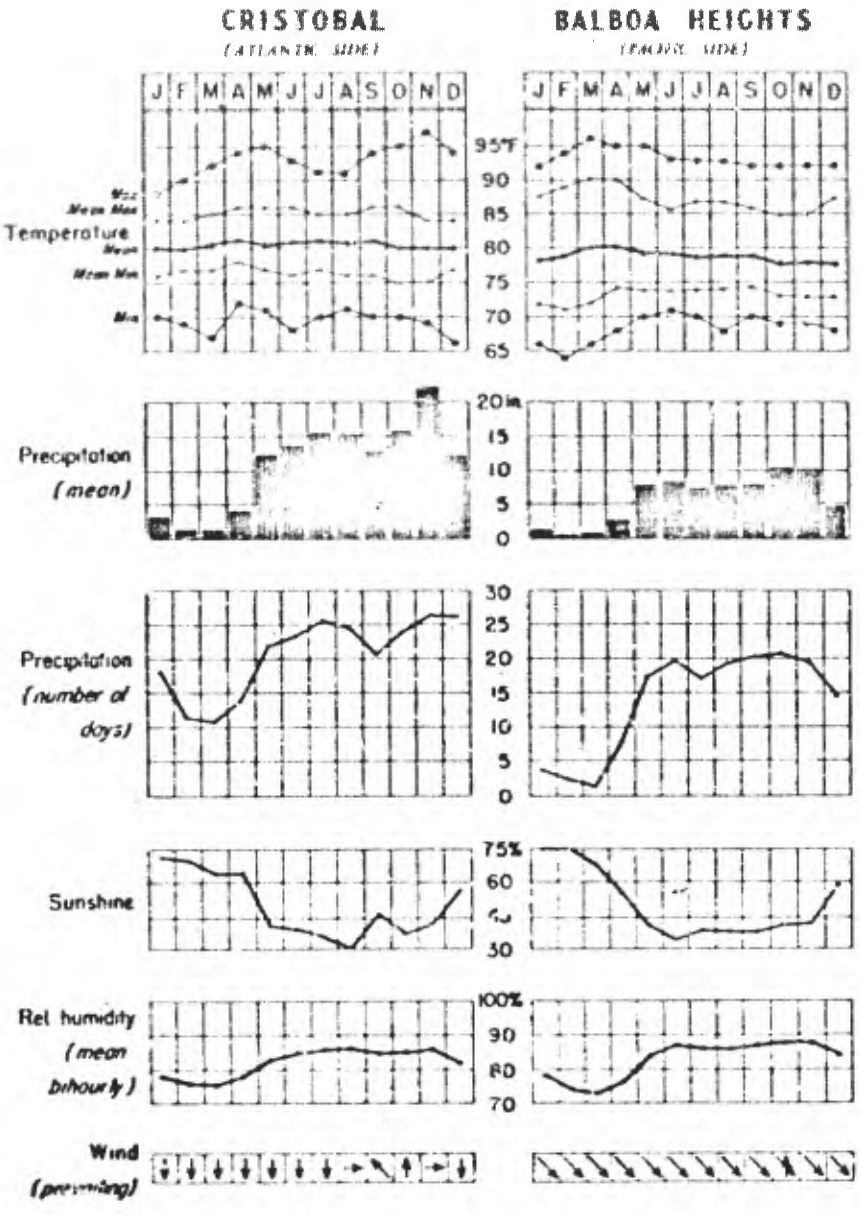

Figure 1. Climatic summary of two Canal Zone Stations

April, but only about 5 to 6 mph during the remainder of the year. Southeastward toward the coast, there is a slight decrease in rainfall and an increase in temperature, as elevation drops to sea level from 118 feet at Balboa Heights. Rainfall increases to the northwest, averaging 88 inches at Gamboa and 117 inches at Monte Lirio.

The Atlantic portion of the Canal Zone, represented by Cristobal, has a wet tropical climate (Fig. 1). The difference in mean temperatures of the warmest and coolest months is only 2F°, and the range from the highest mean daily maximum (April, May, June, September, and October, 86°F) to the lowest mean daily minimum (October and November, 75°F) is only 11F°. The mean annual temperature of 81°F is typical of equatorial areas. Precipitation averages 130 inches a year, and the monthly distribution is uneven. Although no month can be considered really dry, two months have less than 2 inches of rainfall, while eight months have more than 11 inches. The drier season at Cristobal begins in January (3.4 inches) and ends in April (4.1 inches). During the remaining months, average rainfall ranges from about 12 to 22 inches. Mean relative humidity is high in all months; the lowest mean value, 77 percent, occurs in February and March. Cloud cover is greatest in July, 8 tenths, and least in February, 5.5 tenths. Mean wind speed is greatest in February and March (nearly 15 mph) and least in September (about 6 mph).

4. Criteria and methods

a. Climatic elements selected for study

As in the previous studies of this series, temperature, precipitation, humidity, cloud cover, and wind speed were the climatic elements considered most important to military activities. It was assumed that test authorities are more interested in stress periods (e.g., hottest and wettest) and in annual fluctuations than in the data for specific calendar months; accordingly, the warmest, coldest, wettest, and driest months of the year at each station were selected for study. The following specific climatic elements were studied:

(1) Mean temperature of the warmest month
(2) Mean daily maximum temperature of the warmest month
(3) Mean temperature of the coldest month
(4) Mean daily minimum temperature of the coldest month
(5) Mean daily temperature range of the warmest month
(6) Mean annual precipitation
(7) Mean precipitation of the wettest month
(8) Number of wet months
(9) Relative humidity of the driest month
(10) Mean cloud cover of the wettest month
(11) Mean wind speed of the wettest month

b. "Analogous" and "semianalogous" ranges defined

Classes were established defining the ranges of values considered to be closely analogous to those for Balboa Heights and Cristobal. Fairly narrow limits of analogy were used in order to keep comparisons closely representative of the two reference stations. Table I lists the classes of analogy and semianalogy selected for each element. For temperature, a departure of 4 degrees from the mean at the Canal Zone station was allowed for each analogy class (except where a mean was taken for the two reference stations), and an additional 4 degrees for semianalogy. As for precipitation: the mean annual rainfall of 70 inches at Balboa Heights is somewhat below that normally considered humid equatorial (supporting dense evergreen forest) for a locality with a dry season; therefore, in this tropical deciduous forest the limits of analogy were set at 55 to 85 inches, differentiating it from most of the evergreen rain forest areas, on the upper margin, and savanna areas, on the lower margin. Cristobal, which has a tropical evergreen rain forest type of climate, has a mean annual rainfall of 130 inches. A departure of up to 30 inches of mean annual rainfall was considered analogous to Cristobal, and an additional 30 inches was considered semianalogous. Departures of 5 percent in mean relative humidity, 1 tenth in amount of cloudiness, and 2 mph in wind speed were selected as ranges of analogy for these elements.

c. Explanation of maps

Values are shown for each station, with degree of analogy indicated by a symbol. Isopleths were drawn to show zones of close analogy, and these zones are shaded. Areas of semianalogy were not shaded but were indicated by placing the appropriate symbol on the map and legend for stations having semianalogous conditions. From the separate maps showing analogous areas for each element, two composite maps were prepared, one for Balboa Heights and one for Cristobal, indicating regions where the following four single elements are analogous: mean temperature of the warmest month, mean temperature of the coldest month, mean annual precipitation, and number of wet months.

d. Limitations of data

The procedures as outlined have certain definite limitations in a climatic comparison of this sort. Foremost among these is the necessity, often encountered in climatology, of assuming climatic conditions in areas having few if any stations.

A second limitation is that some elements, such as dew point, solar radiation, and visibility, which would have proved valuable as indicators of climatic analogy, were not included in this study because of the limited amount of data available.

For certain elements the number of stations reporting does not provide a representative picture. Consequently, isopleths were not drawn for mean relative humidity for the driest month, mean cloudiness for the wettest month, or mean wind speed for the wettest month.

The assumption has been made that Balboa Heights and Cristobal are representative of the Pacific and Atlantic portions of the Canal Zone.

Data from some Indian and Southeast Asian stations are not given in a form directly comparable to that for the Balboa Heights or Cristobal records. Where period of record, hours of observation, or manner of observation differed, station records had to be interpreted in drawing the isopleths. Values outside the limits of analogy or semianalogy were not analyzed, nor were combinations of climatic elements other than those involved in computing number of wet months.

The method of recording temperatures varies from country to country. Mean temperatures are usually determined by averaging the daily maximum and minimum temperatures; however, at some stations in India and Southeast Asia the means are obtained by averaging bi-hourly temperature observations as at Balboa Heights and Cristobal. Experience has shown that the difference between mean temperatures derived by these different ways is seldom more than 1°. Hours of observation of relative humidity, wind speed, and cloudiness vary widely throughout the study area.

5. Analysis of single-element maps

Individual maps showing analogous areas have been prepared for the climatic elements listed in paragrpah 4a above, numbers 1 through 8. Maps of elements 9, 10, and 11 have been prepared showing only the values for individual stations, since the data were considered inadequate for delimiting analogous areas.

The stations shown on the station location map have been selected from a larger number for greater clarity of the map.

a. Mean Temperature, Warmest Month (Fig. 3)

Balboa Heights and Cristobal have almost the same mean temperatures for the warmest month (80°F and 82°F, respectively). Figure 3 therefore shows only one zone of analogy, lying between the 77° and 85° isotherms.

Most parts of India and Southeast Asia which are not analogous for this element are too hot during the subtropical spring season. Lowlands are analogous in the southern part of the study area and also in Bengal and Assam where "mango rains" moderate spring temperatures. Another area occurs south of Bombay on a coastal strip which is cooled by sea breezes. Other areas of analogy are all moderately high uplands.

h. Number of Wet Months (Fig. 10)

In this series of analogs the term "wet month" is based on the Thornthwaite (1931) formula, having a base mean temperature of 68°F and a mean monthly precipitation of 1.96 inches or more. Mean monthly precipitation for any given mean monthly temperature must be at least as high as the values indicated below in order to be called wet.

Mean monthly temperature (°F)	Mean monthly precipitation (in.)
95	2.88
90	2.71
85	2.54
80	2.37
75	2.20
70	2.03
68	1.96

Using the above definition, the areas of analogy for wet months are 8 to 10 wet months for Balboa Heights and 9 to 11 wet months for Cristobal. Owing to the strong seasonality of monsoon precipitation, most of the study area has too long a dry season to be analogous to the Canal Zone. Areas with 12 wet months are very small, appearing on the map only in a small strip connecting the southwest coast of Ceylon with its uplands, in a small mountain area in northern Indochina, and on the eastern Malay coast near Kota Bharu. Most of Ceylon is analogous; small areas on the north and east coasts are the only parts too dry for analogy. An area of analogy of similar extent, but lacking a core of year-round wet conditions, occurs on the hilly west side of southernmost India. Except for eastern Bengal and Assam the rest of India and Pakistan are too dry for analogy. The lowlands of southeast Asia are mostly nonanalogous for the same reason. Eastern Bengal, Assam, and the higher parts of the Shan-Laos Upland are the main exception to the rule that analogous areas occur either in the lower latitudes of the study region or where the winter monsoon blows inland after passing over the sea for a few hundred miles.

i. Relative Humidity, Driest Month (Fig. 11)

Relative humidities of the driest month of 70 to 80 percent and 72 to 82 percent are considered analogous for Balboa Heights and Cristobal respectively. Isopleths for this map were not drawn because of the inconsistency of records for this element. The data for individual stations indicate no considerable area of analogy except in southeastern Indochina; most of the study area is less humid than the Canal Zone in the dry season.

j. Mean Cloudiness, Wettest Month (Fig. 12)

Balboa Heights and Cristobal both have a mean of 7.6 tenths cloud

cover in their wettest month; 7.0 - 8.9 tenths is considered analogous. No areas of analogy are drawn because of sparsity of data, but inspection of the scattered stations shows that analogy is extremely widespread.

k. Mean Wind Speed, Wettest Month (Fig. 13)

The mean wind speed of the wettest month at Cristobal is 8 mph; at Balboa Heights it is 5.8 mph. A range of 2 mph on each side of each mean is considered analogous. Balboa Heights analogy thus extends from 4 to 8 mph and Cristobal analogy from 6 to 10 mph. No areas of analogy are drawn on Figure 13 because of sparsity of data. Generally speaking, analogy or semianalogy with Balboa Heights is more widely distributed in the study area than analogy or semianalogy with the windier Cristobal station.

6. Analysis of composite maps (Fig. 14 and 15)

Two maps show composite analogous areas for Balboa Heights (Fig. 14) and Cristobal (Fig. 15). These composites consist of analogy of the following criteria for each Canal Zone station: mean temperature of the warmest month, mean temperature of the coldest month, and mean annual precipitation. Any area analogous with respect to these elements was tested for complete analogy by plotting the analogous areas of the number of wet months. On both maps there is a conspicuous lack of analogy in northern Pakistan, India west of Bengal, and in the interior regions of Peninsular India. Areas of dual analogy for mean annual precipitation plus mean temperature of the warmest month are fairly common elsewhere in the study area. Triple analogy is closely confined to the tropical lowlands because the rest of the area is too cold in winter. Areas of composite analogy are very limited, particularly for Cristobal, with its very short dry season.

7. Tables of monthly values

Tables II through IX show the monthly and yearly means of the climatic elements for 25 India and Southeast Asia key stations as well as the two Canal Zone stations. These stations were selected for length of reliable record and representativeness. In each table the mean values for the stations reveal certain characteristics of climatic analogy which are not evident in the maps. For example, a truer climatic picture is presented when the length and frequency of the dry season are known.

Ceylon is represented by Colombo on the coast and Nuwara Eliya in the highland. The coasts of Peninsular India are represented by Bombay, on the Arabian Sea, and Madras, on the Bay of Bengal. Bangalore, Hyderabad, and Nagpur are interior peninsular stations covering a considerable range of latitude and altitude. Poona is just east of the crest of the Western Ghats, inland from Bombay. Delhi represents the more interior part of the Indo-Gangetic Lowland, Dibrugarh, the Brahmaputra Valley; Calcutta the

Bengal Lowlands at the head of the Bay of Bengal. Simla is in the drier mountains of the northwest, and Cherrapunji is in the wetter, more tropical mountains of eastern India and the Burmese border. Mandalay represents the interior Irrawaddy Lowland, and Rangoon the Irrawaddy delta area. Burmese coastal stations are Diamond Island, on the tip of a peninsula facing the southwest monsoon, and Tavoy, which is backed by mountains. Kota Bharu, Malaya, has the lowest latitude of any station in the area. Bangkok and Saigon are in the southern Menam-Mekong Lowland. Dalat is on the crest of the southern Annam Highlands; Nhatrang is a coastal station northeast of Dalat. Luang Prabang represents the Shan-Laos Upland. Chapa is a high-level station on an Indochinese outlier of the mountains of southern China. Hanoi represents the Tonkin Lowland.

TABLE I: CLIMATIC ELEMENTS AND CLASSES OF ANALOGY

Station index	Balboa Heights			Cristobal		
	Value at B.H. (mean)	Analogous (range)	Semianalogous (range)	Value at Cris. (mean)	Analogous (range)	Semianalogous (range)
TEMPERATURE (°F)			73-76			73-76
Mean, warmest month*	80	77-85	86-89	82	77-85	86-89
Mean daily maximum, warmest month	90	86-94	82-85 95-98	86	82-90	78-81 91-94
Mean coldest month*	78	75-83	71-74 84-87	80	75-83	71-74 84-87
Mean daily minimum, coldest month	71	67-75	63-66 76-79	75	71-79	67-70 80-83
Mean daily range, warmest month	16	12-20	8-11 21-24	8	4-12	0-3 13-16
PRECIPITATION						
Mean annual (inches)	70	55-85	40-54 86-100	130	100-160	70-99 161-190
Mean, wettest month (inches)	11	8-14	5-7 15-17	22	15-29	8-14 30-36
Number of wet months	9	8-10	7 11	10	9-11	8 12
RELATIVE HUMIDITY (%)			65-69			67-71
Mean, driest month	75	70-80	81-85	77	72-82	83-87
CLOUDINESS (tenths)			6.0-6.9			6.0-6.9
Mean, wettest month	7.6	7.0-8.9	9.0-10.0	7.6	7.0-8.9	9.0-10.0
WIND SPEED (mph)			2-3			4-5
Mean, wettest month	5.8	4-8	9-10	8	6-10	11-12

*See section 4b for explanation of ranges of analogy; sometimes a mean of the 2 reference stations is used.

TABLE II: STATIONS USED IN TABLES OF MONTHLY VALUES

Stations	Altitude (ft)	Latitude (N)	Longitude (W)	Record (Yrs)*
BALBOA HEIGHTS (Canal Zone)	118	8° 58'	79° 35' W	12
Bangalore (India)	3,022	12° 58'	77° 35'	51
Bangkok (Thailand)	*	13° 44'	100° 30'	17
Bombay (India)	37	18° 58'	72° 50'	56
Calcutta (India)	23	22° 32'	88° 20'	42
Chapa (North Viet Nam)	5,381	22° 22'	103° 52'	10
Cherrapunji (India)	4,309	25° 15'	91° 44'	**
Colombo (Ceylon)	23	6° 54'	79° 52'	49
CRISTOBAL (Canal Zone)	36	9° 25'	79° 52' W	7
Dalat (South Viet Nam)	4,921	11° 57'	108° 26'	21
Delhi (India)	718	28° 39'	77° 15'	22
Diamond Island (Burma)	42	15° 51'	94° 19'	**
Dibrugarh (India)	348	27° 28'	94° 55'	17
Hanoi (North Viet Nam)	23	21° 03'	105° 52'	30
Hyderabad (India)	1,719	17° 22'	78° 27'	29
Kota Bharu (Malaya)	20	6° 08'	102° 15'	8
Luang Prabang (Laos)	1,115	19° 53'	102° 08'	**
Madras (India)	23	13° 04'	80° 15'	50
Mandalay (Burma)	250	21° 59'	96° 06'	24
Nagpur (India)	1,017	21° 09'	79° 09'	**
Nhatrang (South Viet Nam)	20	12° 15'	109° 12'	31
Nuwara Eliya (Ceylon)	6,148	6° 58'	80° 46'	46
Poona (India)	1,834	18° 32'	74° 51'	17
Rangoon (Burma)	16	16° 47'	96° 13'	40
Saigon (South Viet Nam)	36	10° 47'	106° 40'	29
Simla (India)	7,224	31° 06'	77° 10'	39
Tavoy (Burma)	20	14° 05'	98° 12'	41

* Length of record quoted for each station is the shortest used for either temperatures or precipitation.

** Data in tables are from official sources which do not quote length of record.

TABLE III: MEAN MONTHLY TEMPERATURE (°F)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
TAIPEI HEIGHTS	78	79	80	80	79	79	79	79	79	78	78	78	79
Bangalore	68	72	77	81	80	75	73	73	73	73	70	68	74
Bangkok	77	80	84	85	85	84	82	83	82	81	79	77	81
Bombay	75	75	78	82	85	83	80	80	80	81	80	77	80
Calcutta	67	72	80	86	86	85	84	83	83	81	73	66	79
Chapa	48	49	57	63	65	68	68	66	65	62	57	46	60
Cherrapunji	53	55	61	64	66	68	69	69	69	66	61	55	63
Colombo	79	80	82	82	83	82	81	81	81	80	80	79	81
CRISTOBAL	80	80	81	82	81	81	81	81	81	80	80	80	81
Dalat	62	63	65	67	68	68	67	67	66	65	64	61	65
Delhi	59	63	74	85	92	93	88	86	85	80	69	60	78
Diamond Island	77	78	80	83	84	81	80	80	81	82	81	78	81
Dibrugarh	61	64	69	72	78	81	81	81	81	77	70	62	73
Hanoi	62	63	68	75	82	85	84	84	82	77	71	65	75
Hyderabad	72	77	83	89	92	85	80	79	79	79	74	70	80
Kota Bharu	78	78	80	82	83	82	81	81	81	80	79	78	80
Luang Prabang	69	74	78	82	84	84	82	82	[illegible]	79	75	70	78
Madras	76	78	81	85	89	90	87	85	85	82	79	77	83
Mandalay	71	76	83	90	89	87	87	86	85	83	78	71	82
Nagpur	70	74	82	90	95	89	82	81	81	79	73	68	80
Nhatrang	75	76	78	81	83	83	83	84	82	80	78	76	80
Nuwara Eliya	57	57	59	61	62	60	59	60	60	60	59	58	59
Poona	70	73	80	85	86	81	77	76	77	78	73	69	77
Rangoon	77	79	84	87	84	81	80	80	81	82	80	77	81
Saigon	79	81	84	86	84	82	81	82	81	81	81	79	82
Simla	41	42	50	58	65	67	65	64	62	58	51	45	56
Tavoy	78	80	82	84	82	79	78	78	79	81	79	77	80

TABLE 10: MEAN DAILY MAXIMUM TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
BALBOA HEIGHTS	86	89	90	90	87	86	87	87	86	85	85	87	87
Bangalore	80	85	90	92	91	84	81	81	82	81	79	78	84
Bangkok	86	88	92	93	92	90	89	89	88	86	85	85	89
Bombay	83	83	86	89	91	88	85	84	85	88	87	85	86
Calcutta	77	82	91	95	95	91	89	88	88	87	82	77	87
Chapa	51	56	61	68	73	72	74	73	70	65	60	58	65
Cherrapunji	60	62	68	70	72	72	72	72	73	72	68	62	69
Colombo	87	88	89	89	88	86	85	85	86	86	86	86	87
CRISTOBAL	84	84	85	86	86	86	85	85	86	86	84	84	85
Dalat	76	79	79	80	79	77	74	75	76	76	74	74	77
Delhi	70	75	86	98	104	103	95	92	93	92	82	73	89
Diamond Island	84	84	85	88	89	86	85	84	85	86	35	84	85
Dibrugarh	71	72	78	80	34	87	87	87	86	84	79	73	81
Hanoi	68	68	73	81	90	92	91	90	88	84	78	72	81
Hyderabad	84	90	97	101	103	94	88	86	86	88	84	82	90
Kota Bharu	34	86	88	90	91	90	89	89	89	87	84	83	88
Luang Prabang	82	89	94	96	95	93	90	90	91	89	85	81	90
Madras	85	87	89	92	98	98	95	94	93	90	86	84	91
Mandalay	84	90	98	102	100	95	95	93	93	92	88	84	93
Nagpur	83	88	94	105	109	99	88	87	89	91	86	82	92
Nhatrang	82	84	86	89	91	91	91	92	89	86	84	82	87
Nuwara Eliya	68	70	72	72	71	65	64	66	66	68	67	67	68
Poona	86	91	97	101	99	89	83	82	85	89	86	85	89
Rangoon	89	92	96	98	92	86	85	85	86	88	87	87	89
Saigon	89	91	93	95	92	89	88	88	88	88	87	87	90
Simla	47	48	56	66	74	75	71	69	69	64	58	50	62
Tavoy	90	92	93	94	89	84	83	83	84	88	89	88	88

TABLE V: MEAN DAILY MINIMUM TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
BAIAN HEIGHTS	72	71	72	74	74	74	74	74	74	73	73	73	73
Bangalore	68	72	77	81	80	75	73	73	73	73	70	68	84
Bangkok	65	72	76	77	77	77	76	76	76	75	72	77	74
Bombay	68	69	73	77	81	80	76	77	77	77	74	70	75
Calcutta	56	60	69	76	78	79	79	78	78	75	65	56	71
Chapa	41	44	50	54	59	61	64	62	59	54	50	46	54
Cherrapunji	53	55	61	64	66	68	69	69	69	66	61	55	57
Colombo	72	72	74	76	78	77	77	77	77	75	74	73	75
CRISTOBAL	76	77	77	78	77	76	77	76	76	75	76	77	76
Dalat	50	50	52	55	59	60	60	60	59	57	55	53	56
Delhi	48	52	62	73	80	84	81	80	77	68	57	49	67
Diamond Island	71	73	75	79	79	77	76	76	76	77	76	72	76
Dibrugarh	50	55	61	65	71	74	75	76	75	70	60	51	65
Hanoi	56	58	62	69	74	77	78	77	76	70	64	59	68
Hyderabad	60	64	70	76	80	76	73	72	72	69	63	58	69
Kota Bharu	72	71	72	74	74	74	73	73	73	73	73	72	72
Luang Prabang	56	58	63	69	73	75	75	74	74	69	64	56	67
Madras	67	68	72	77	81	81	78	77	77	75	72	69	74
Mandalay	71	76	83	90	89	87	87	86	85	83	78	71	82
Nagpur	56	60	67	76	82	79	75	75	74	68	60	54	69
Nhatrang	69	68	71	74	75	76	76	76	75	73	72	70	73
Nuwara	47	45	46	49	53	55	54	53	53	52	51	49	51
Poona	53	55	62	69	73	74	72	70	69	66	59	53	65
Rangoon	65	66	71	76	77	76	76	76	76	75	73	67	73
Saigon	70	71	74	76	76	75	74	75	74	74	73	71	74
Simla	35	36	43	50	57	60	59	59	56	51	44	39	49
Tavoy	65	68	71	75	75	75	74	74	74	73	70	65	72

TABLE VI: MEAN MONTHLY PRECIPITATION (inches)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
BALBOA HEIGHTS	1.0	0.6	0.7	2.9	9.0	8.4	7.3	7.8	8.2	10.2	10.5	4.3	70.3
Bangalore	0.2	0.3	0.5	1.5	4.3	2.8	4.1	5.2	6.6	6.0	2.5	0.5	34.5
Bangkok	0.3	0.8	1.4	2.3	7.8	6.3	6.3	6.9	12.0	8.1	2.6	0.2	55.0
Bombay	0.1	0.1	0.1	0.1	0.8	18.3	24.3	13.8	10.5	2.2	0.4	0.1	70.8
Calcutta	0.4	1.0	1.3	2.1	5.5	11.7	12.7	13.3	10.0	4.9	0.7	0.2	63.9
Chapa	1.5	3.1	4.6	7.5	6.1	14.2	18.1	18.3	13.2	7.0	5.0	1.6	112.5
Cherrapunji	0.4	2.7	9.4	28.2	46.3	95.9	98.5	79.8	38.0	21.3	3.2	0.3	434.0
Colombo	3.5	2.1	4.3	9.8	12.4	7.7	4.7	3.7	5.4	13.7	12.2	5.3	85.1
CRISTOBAL	3.4	1.5	1.5	4.1	12.5	13.9	15.6	15.3	12.8	15.8	22.3	11.7	130.4
Dalat	0.4	1.0	2.2	6.5	8.5	7.3	9.6	8.3	12.1	10.0	3.9	1.1	71.0
Delhi	1.0	0.7	0.4	0.3	0.6	3.2	7.7	7.5	4.6	0.4	0.1	0.5	27.1
Diamond Island	0.1	0.1	0.2	1.3	11.2	25.2	27.6	25.5	17.3	8.4	5.0	0.8	122.7
Dibrugarh	1.6	2.3	3.2	9.3	13.2	19.8	20.8	18.4	15.6	6.5	1.6	0.7	113.3
Hanoi	0.9	1.4	1.8	3.6	8.6	10.2	13.4	13.4	10.5	4.4	2.0	1.1	71.2
Hyderabad	0.2	0.3	0.7	1.0	1.0	4.6	6.5	7.3	7.0	3.2	1.1	0.2	32.3
Kota Bharu	10.3	6.7	7.0	4.5	6.2	6.4	5.6	6.7	8.6	11.5	22.5	27.5	123.9
Luang Prabang	0.6	0.7	1.2	4.2	6.5	6.2	8.8	11.9	6.7	2.9	1.2	0.5	51.5
Madras	1.2	0.4	0.4	0.6	1.7	1.9	3.7	4.6	4.7	11.5	13.5	5.2	49.4
Mandalay	0.0	0.1	0.2	1.1	5.5	5.4	3.4	4.1	6.5	4.7	1.7	0.3	33.3
Nagpur	0.4	0.6	0.5	0.6	0.8	9.0	13.8	11.6	8.2	2 .	0.7	0.5	49.0
Nhatrang	2.3	0.9	1.7	0.9	2.6	1.8	1.8	2.0	6.7	13.4	15.1	7.4	56.7
Nuwara Eliya	6.0	2.1	3.5	5.6	7.7	12.1	11.5	7.6	8.1	10.6	9.0	8.2	92.2
Poona	0.1	0.0	0.1	0.6	1.2	4.0	5.7	3.6	6.3	3.1	1.3	0.1	26.1
Rangoon	0.1	0.2	0.3	1.6	12.4	18.1	21.2	19.5	15.6	7.0	2.5	0.1	98.7
Saigon	0.6	0.1	0.5	1.6	8.5	12.5	12.2	10.6	13.1	10.5	4.5	2.2	77.7
Simla	3.0	3.1	2.6	2.2	3.2	7.0	17.8	17.8	6.5	1.2	0.5	1.2	66.0
Tavoy	0.2	0.5	1.3	3.4	19.8	43.5	48.9	45.0	32.6	10.4	2.3	0.2	208.3

TABLE VII: MEAN CLOUDINESS (tenths of sky covered)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
BAIKOA HEIGHTS	5.8	4.8	5.0	6.3	7.6	8.0	7.6	7.7	7.7	7.7	7.6	6.3	6.8
Bangalore*	3.3	1.9	1.4	2.9	4.3	7.3	8.5	8.5	8.0	6.1	4.7	4.1	5.1
Bangkok*	2.0	2.7	3.0	3.8	5.7	5.8	6.3	5.9	6.9	5.6	3.2	1.9	4.4
Bombay **	---	---	---	---	---	---	---	---	---	---	---	---	---
Calcutta	0.8	1.8	1.9	2.5	4.4	6.9	8.4	8.3	7.1	3.7	1.8	1.1	4.0
Chapa*	7.0	7.0	6.5	6.0	5.5	6.8	6.8	7.0	7.0	7.0	6.0	5.0	6.5
Cherrapunji*	3.2	4.1	3.1	5.6	7.0	9.0	8.8	8.8	7.5	5.3	4.2	1.4	5.8
Colombo**	---	---	---	---	---	---	---	---	---	---	---	---	---
CRISTOBAL	5.9	5.5	5.8	6.4	7.8	7.9	8.0	7.6	7.1	7.4	7.6	6.8	7.0
Dalat*	5.3	5.1	5.7	7.2	7.7	7.8	8.2	8.0	8.1	7.7	7.1	6.5	7.0
Delhi	3.3	3.2	3.0	2.4	2.1	4.0	6.0	6.4	2.8	0.8	0.9	1.6	3.0
Diamond Island**	---	---	---	---	---	---	---	---	---	---	---	---	---
Dibrugarh*	5.3	5.1	5.0	6.3	7.0	7.7	8.1	7.9	7.6	5.4	3.8	3.3	6.0
Hanoi	7.6	8.4	8.7	8.2	7.4	7.8	7.7	7.6	6.7	6.1	6.6	6.9	7.5
Hyderabad	1.2	1.4	1.1	2.6	3.2	6.2	7.6	7.2	6.5	3.6	2.7	1.6	3.7
Kota Bharu*	6.4	4.5	4.7	4.9	6.0	6.3	7.1	6.2	7.0	7.1	7.0	7.0	6.2
Luang Prabang*	4.8	2.8	2.8	3.2	4.5	5.2	6.0	6.8	4.5	4.0	4.5	4.5	4.9
Madras	3.5	2.6	2.0	3.4	3.6	6.0	7.0	6.6	5.9	5.6	5.6	4.9	4.7
Mandalay	0.7	0.7	0.9	1.8	4.6	6.2	7.9	7.2	5.9	3.9	3.2	2.2	3.8
Nagpur*	2.7	2.1	1.9	2.5	2.6	6.1	8.2	7.8	6.4	3.3	2.8	2.4	4.1
Nhatrang	6.7	5.4	5.2	5.0	5.5	5.8	6.1	6.0	6.8	7.2	7.5	7.1	6.2
Nuwara Eliya*	5.8	4.7	4.8	6.0	6.9	8.3	8.4	7.9	7.8	7.6	7.3	6.6	6.8
Poona	1.0	0.7	1.5	1.9	2.2	6.7	8.7	8.3	7.1	4.2	2.2	1.7	3.8
Rangoon	3.0	2.8	3.6	4.1	7.3	8.9	9.2	9.1	8.6	6.5	4.5	3.4	5.9
Saigon	5.3	4.6	4.9	5.7	7.2	7.8	8.1	7.9	8.1	7.4	6.7	6.3	6.7
Simla	4.8	4.8	3.9	3.1	2.8	5.1	8.3	8.1	4.9	0.8	1.7	3.5	4.3
Tavoy*	3.4	3.3	3.7	5.6	8.2	9.1	9.4	9.2	8.8	7.2	5.7	3.7	6.4

* Data may not approximate a true diurnal mean because of an inadequate schedule of observations

** No data available

TABLE VIII: MEAN RELATIVE HUMIDITY (%)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
BALBOA HEIGHTS	78	75	73	77	85	87	86	87	87	88	88	84	83
Bangalore	62	54	50	55	63	74	77	79	80	78	75	70	68
Bangkok*	66	60	63	62	65	69	68	66	73	74	68	67	67
Bombay	73	71	75	77	77	82	87	87	86	81	73	72	78
Calcutta	78	66	67	70	75	83	87	88	86	82	74	70	77
Chapa	76	84	86	80	79	86	86	87	90	88	87	82	84
Cherrapunji*	72	70	58	72	83	92	92	92	86	78	84	71	78
Colombo	80	80	80	82	82	83	82	82	82	84	84	82	82
CRISTOBAL	78	77	77	79	83	85	86	86	85	85	86	82	82
Dalat	82	80	78	82	87	86	88	86	87	87	84	84	84
Delhi	60	50	44	34	40	51	73	74	70	55	48	54	55
Diamond Island**	--	--	--	--	--	--	--	--	--	--	--	--	--
Dibrugarh*	96	90	81	83	87	91	92	92	92	88	89	95	90
Hanoi	82	86	86	88	85	84	86	86	86	82	81	82	84
Hyderabad	57	50	44	46	42	64	74	80	81	69	66	61	61
Kota Bharu*	82	81	79	79	79	80	81	81	80	83	85	85	81
Luang Prabang	83	75	71	73	80	84	87	87	86	84	84	85	82
Madras	79	78	78	78	70	66	68	73	77	83	84	82	76
Mandalay	83	68	54	58	72	75	75	79	83	83	85	86	75
Nagpur*	55	45	34	30	30	58	81	80	77	64	57	56	56
Nhatrang	79	80	81	82	82	81	80	81	84	85	84	81	82
Nuwara Eliya*	70	59	63	68	76	84	84	82	80	78	79	76	68
Poona	42	35	32	35	50	72	80	83	78	62	49	44	55
Rangoon	82	84	85	80	86	91	92	93	92	90	86	82	87
Saigon	77	75	74	76	83	86	87	86	88	87	84	81	82
Simla	61	61	49	43	46	61	88	91	80	53	51	48	61
Tavoy*	75	76	74	75	85	92	93	92	92	86	80	73	83

* Data may not approximate a true diurnal mean because of an inadequate schedule of observations

** No data available

TABLE IX: MEAN WIND SPEED (mph)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
BALBOA HEIGHTS	8.8	10.2	10.3	8.8	6.1	5.9	5.9	5.9	5.6	6.3	5.8	6.4	7.1
Bangalore	4.7	4.4	4.2	4.0	5.1	7.5	7.5	6.6	5.3	3.8	4.1	4.5	5.1
Bangkok	4.1	5.0	6.1	5.7	5.2	4.7	4.4	4.8	5.2	4.7	4.0	3.9	4.8
Bombay*	---	---	---	---	---	---	---	---	---	---	---	---	---
Calcutta	2.2	2.8	3.6	4.9	4.8	4.3	4.0	3.4	2.8	2.1	2.1	2.1	3.3
Chapa	4.4	6.8	3.6	9.1	5.1	5.5	4.0	4.7	2.6	4.0	1.4	6.4	4.8
Cherrapunji	3.0	4.5	6.2	6.3	4.7	4.9	4.6	3.7	3.2	2.5	2.2	1.9	4.0
Colombo	5.2	4.4	3.8	4.0	5.6	6.3	5.9	6.2	5.9	4.5	4.0	5.2	5.1
CRISTOBAL	14.1	14.8	14.8	12.5	8.0	6.6	8.1	7.9	6.1	6.6	8.0	11.8	9.9
Dalat	8.7	7.4	7.0	5.6	5.8	6.7	9.4	7.6	6.6	6.4	7.6	8.9	7.3
Delhi	2.2	2.6	2.0	3.1	3.5	3.9	3.5	3.1	2.8	1.8	1.6	1.9	2.7
Diamond Island	---	---	---	6.8	7.1	9.2	10.0	9.0	7.4	7.3	---	---	---
Dibrugarh	0.4	0.8	1.2	1.3	0.9	0.8	0.7	0.7	0.5	0.5	0.4	0.3	0.7
Hanoi	6.9	5.8	5.4	6.4	5.9	5.2	5.3	5.0	6.4	6.6	6.4	6.4	6.4
Hyderabad	2.3	2.7	2.6	3.0	4.3	6.5	6.7	5.9	3.8	2.6	2.4	2.1	3.7
Kota Bharu*	---	---	---	---	---	---	---	---	---	---	---	---	---
Luang Prabang	2.4	3.0	2.4	3.0	3.0	1.9	1.5	1.7	2.2	3.1	2.7	1.6	2.4
Madras	4.1	3.6	4.4	5.4	6.3	6.4	5.5	4.9	4.2	3.4	4.5	5.1	4.8
Mandalay	1.5	1.9	2.8	4.2	4.7	6.0	6.5	5.7	3.5	2.4	1.7	1.7	3.5
Nagpur	2.5	3.1	3.5	4.2	5.5	5.2	6.0	5.1	3.7	2.7	2.6	2.2	3.9
Nhatrang	8.5	8.9	6.9	6.9	5.8	5.4	5.4	5.4	4.5	4.5	6.9	7.8	6.5
Nuwara Eliya	3.4	3.6	3.2	3.1	3.9	6.4	6.1	5.2	4.7	4.1	3.1	3.2	4.2
Poona	4.5	5.0	6.1	7.6	10.6	11.2	11.6	10.2	7.9	4.8	4.5	4.3	7.4
Rangoon	2.7	2.7	3.3	4.2	3.5	3.7	3.7	3.3	2.6	2.2	2.7	3.1	3.1
Saigon	5.3	7.5	8.8	8.3	5.3	5.0	6.9	6.6	5.3	4.1	4.5	4.1	6.0
Simla	4.1	4.1	4.5	4.4	4.2	3.4	2.7	2.5	2.8	3.1	2.9	3.4	3.5
Tavoy	1.8	1.8	1.9	2.1	2.2	2.5	2.6	2.3	1.8	1.7	1.8	1.9	2.0

* No data available

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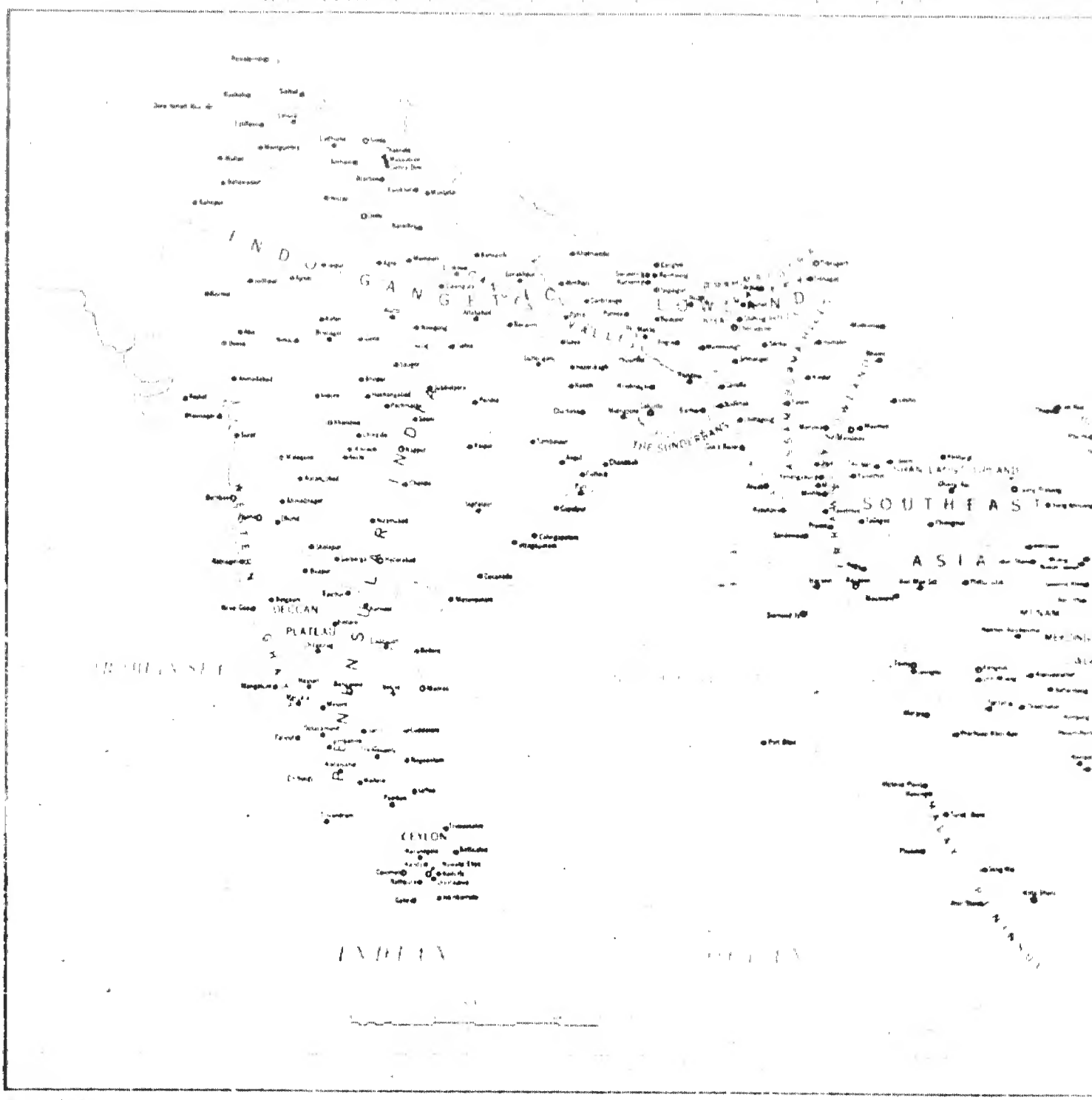
9. Acknowledgments

The maps for this report were drafted and printed by the Waterways Experiment Station, U. S. Army Corps of Engineers, Vicksburg, Mississippi, from fair sheets prepared by the author.

10. Maps

Figure	
2	Station Locations
3	Mean Temperature, Warmest Month
4	Mean Daily Maximum Temperature, Warmest Month
5	Mean Temperature, Coldest Month
6	Mean Daily Minimum Temperature, Coldest Month
7	Mean Daily Temperature Range, Warmest Month
8	Mean Annual Precipitation
9	Mean Monthly Precipitation, Wettest Month
10	Number of Wet Months
11	Relative Humidity, Driest Month
12	Mean Cloudiness, Wettest Month
13	Mean Wind Speed, Wettest Month
14	Composite of Analogous Areas - Balboa Heights
15	Composite of Analogous Areas - Cristobal


INDO
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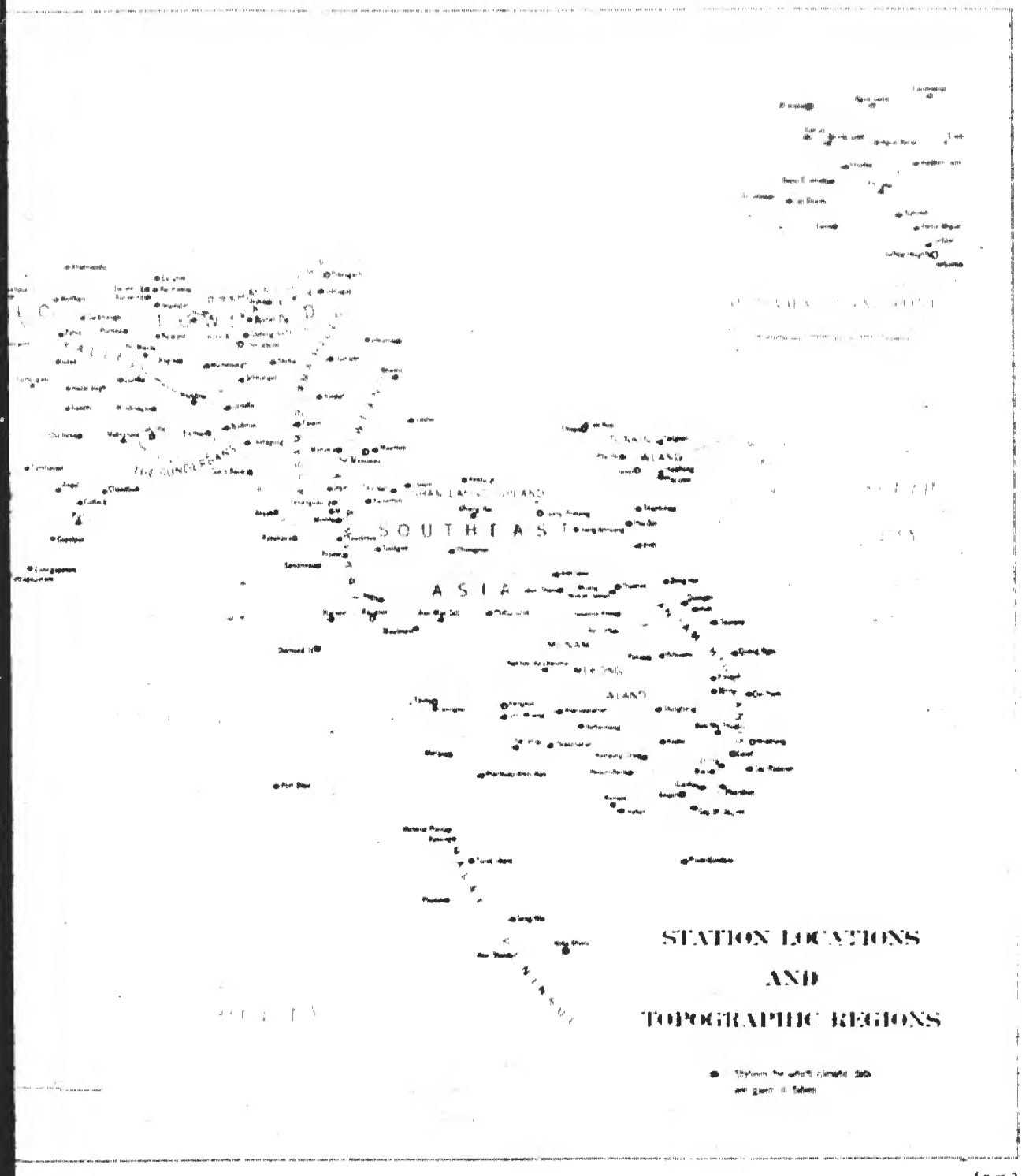
LOWLAND
DECCAN
PLATEAU
CEYLON
SOUTHEAST
ASIA

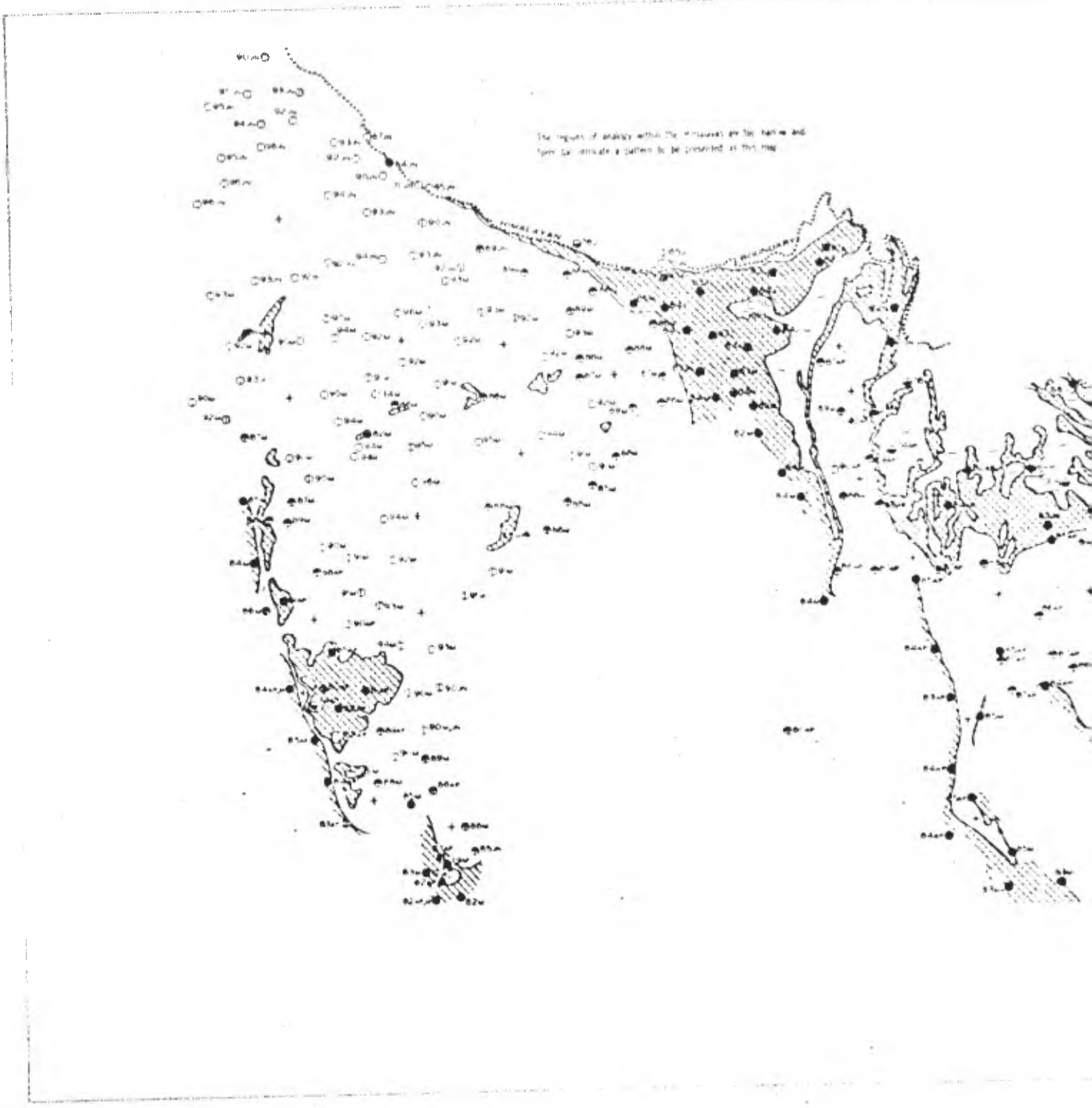


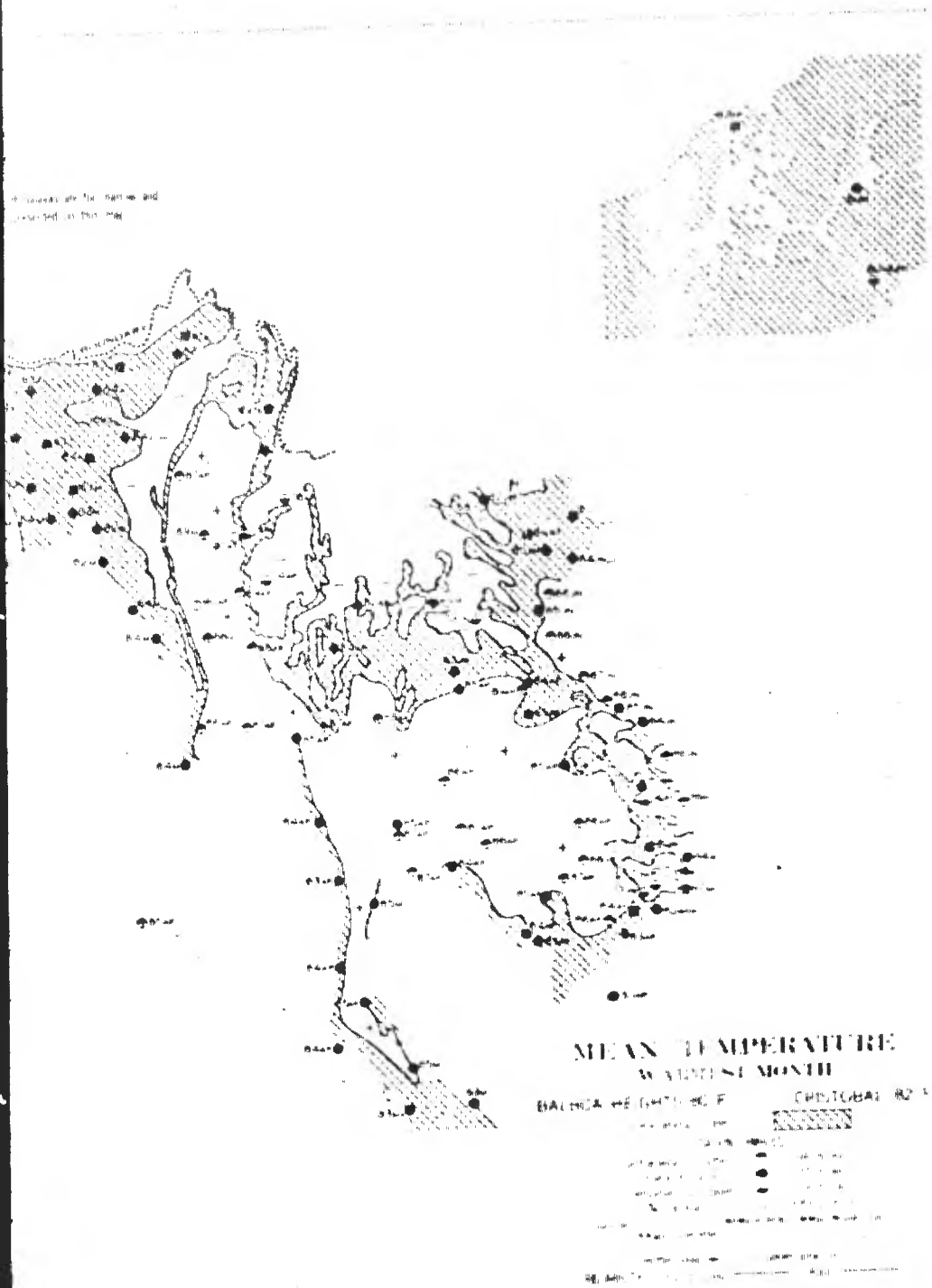
STATION LOCATIONS

AND

TOPOGRAPHIC REGIONS

Figure 2

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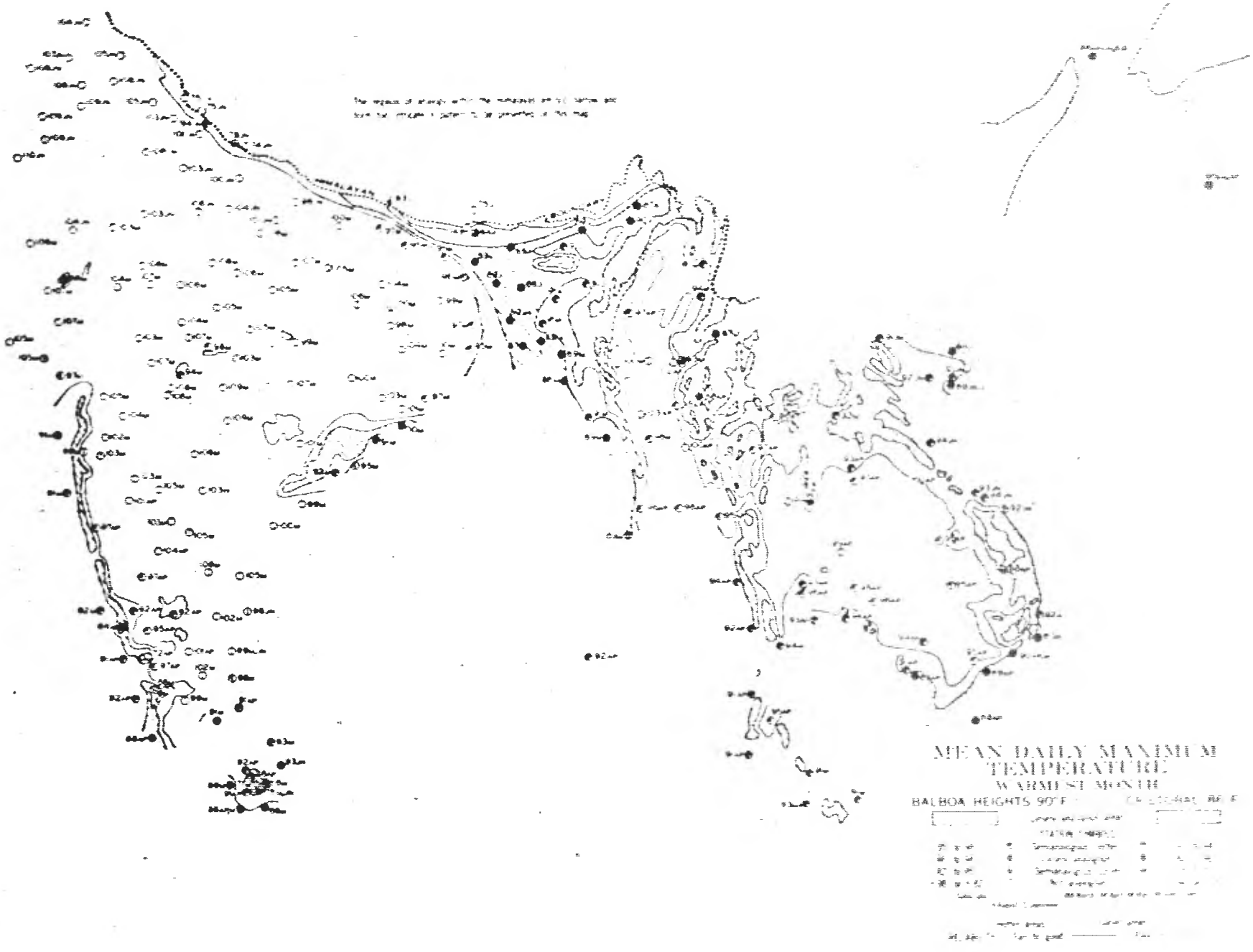
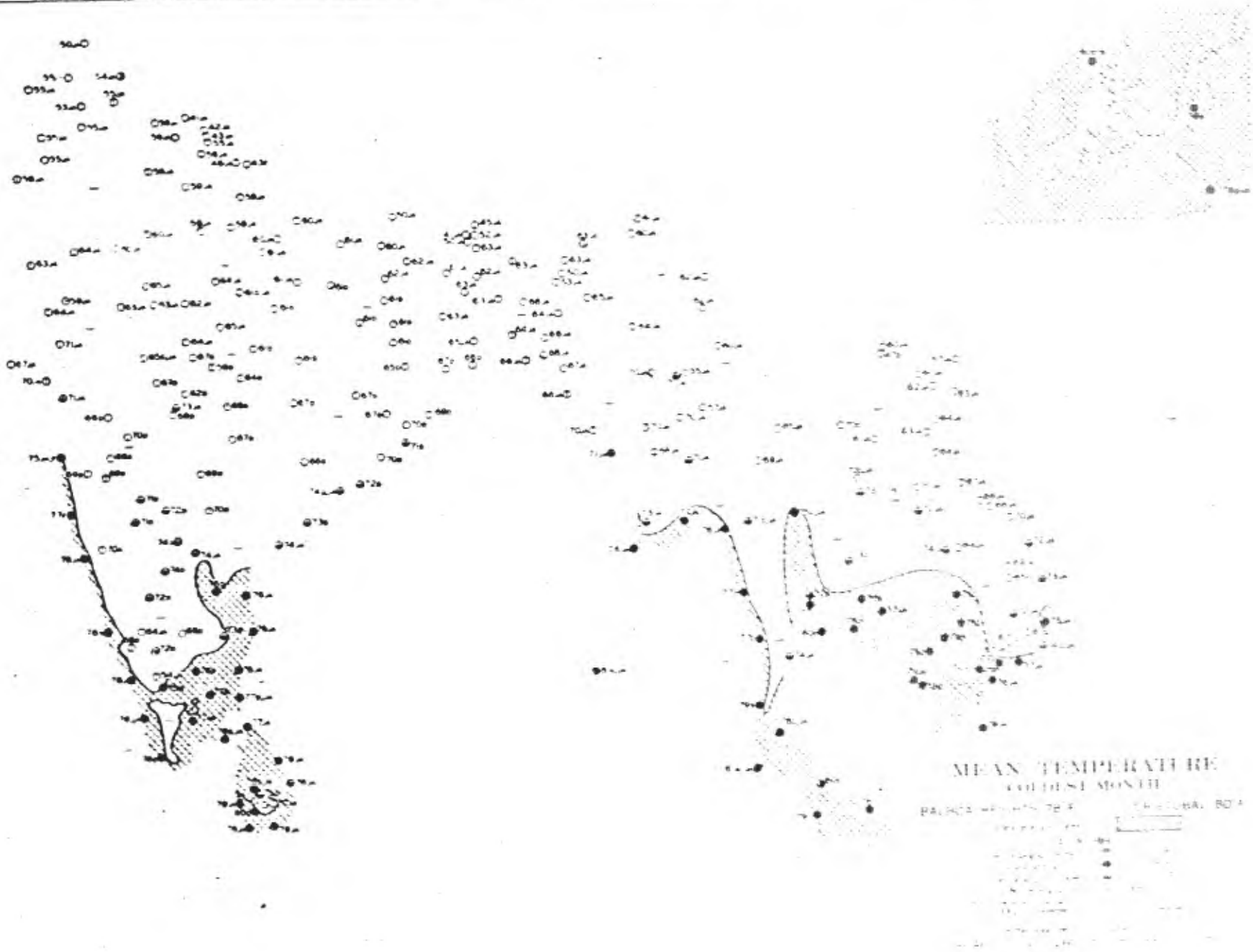
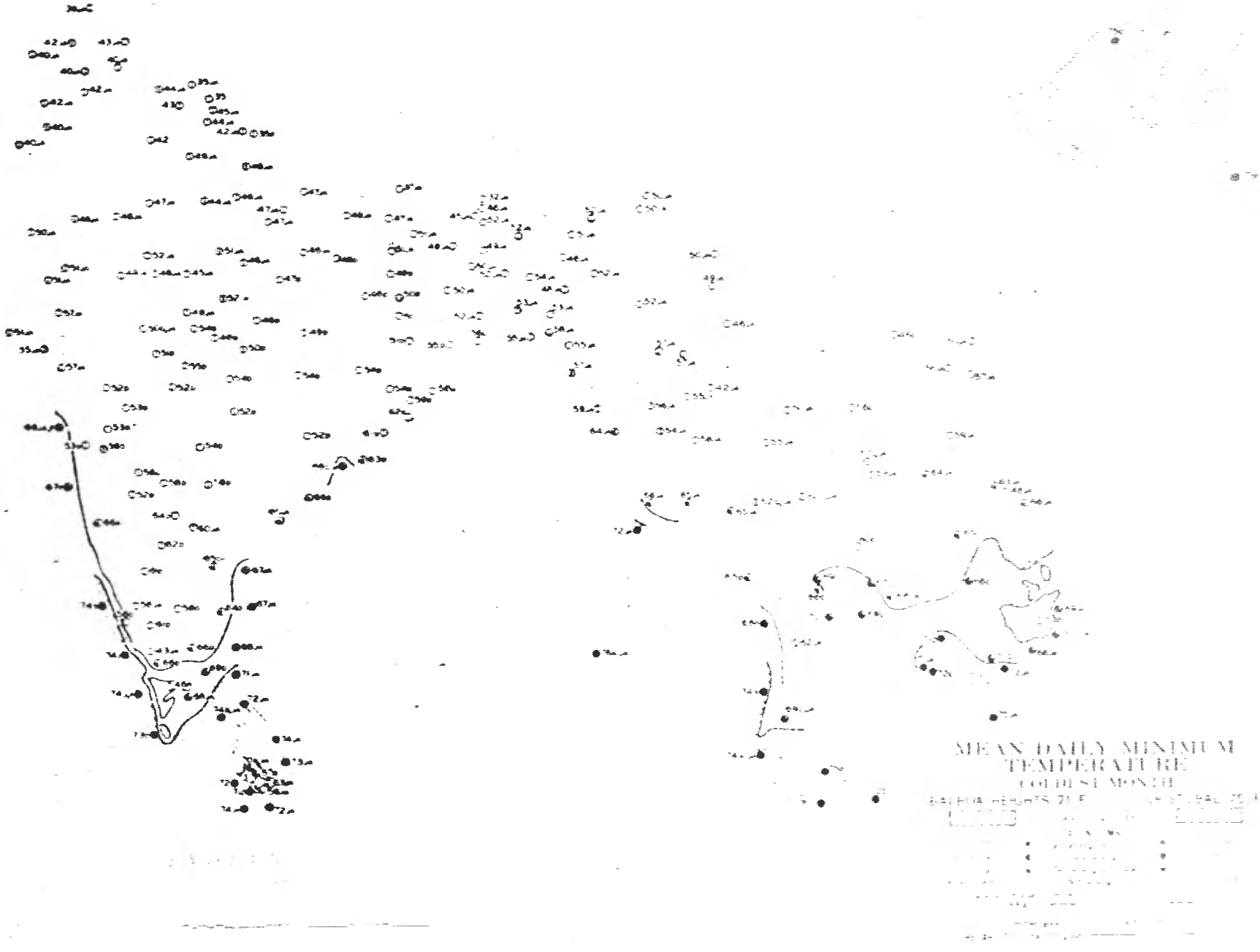
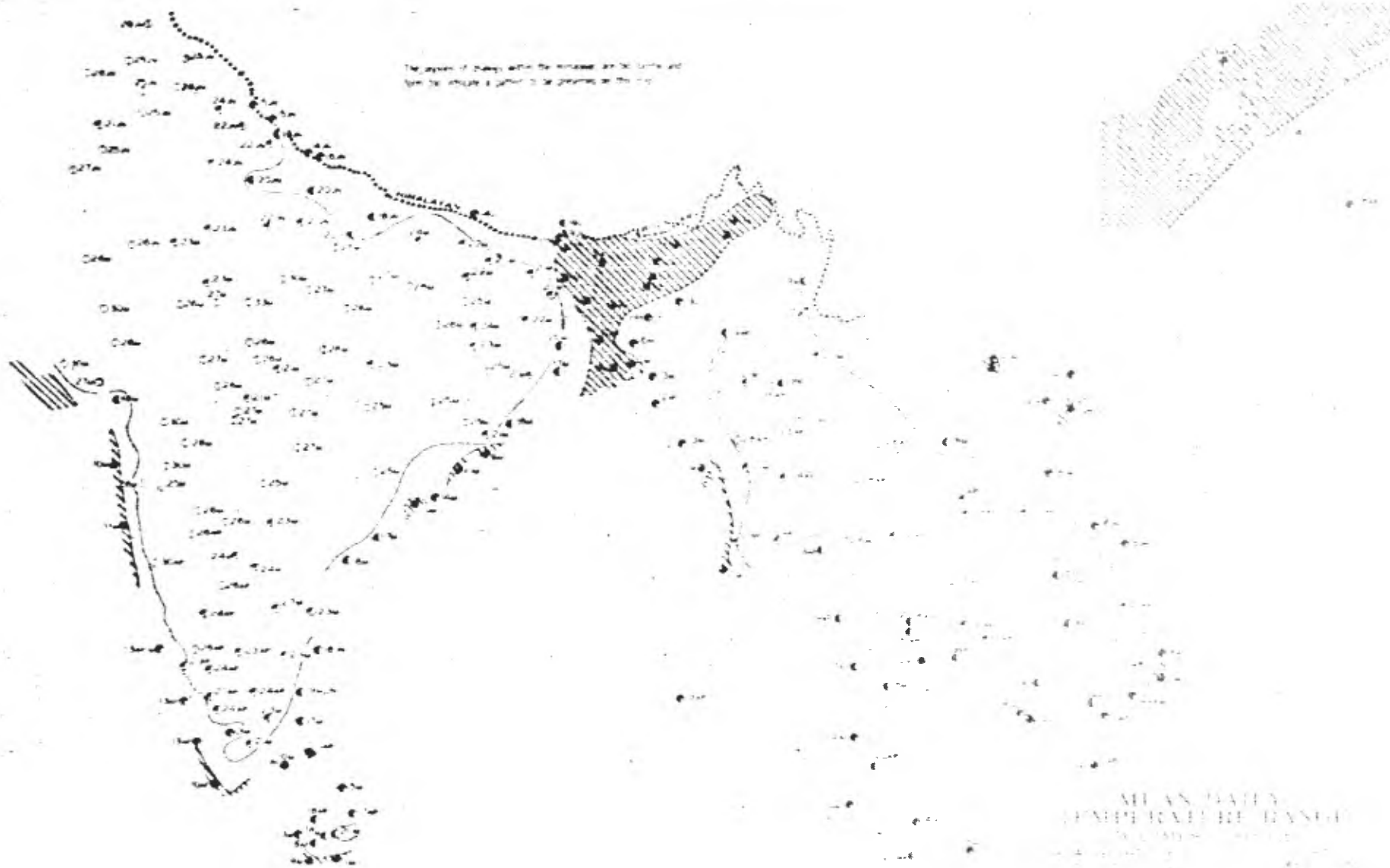
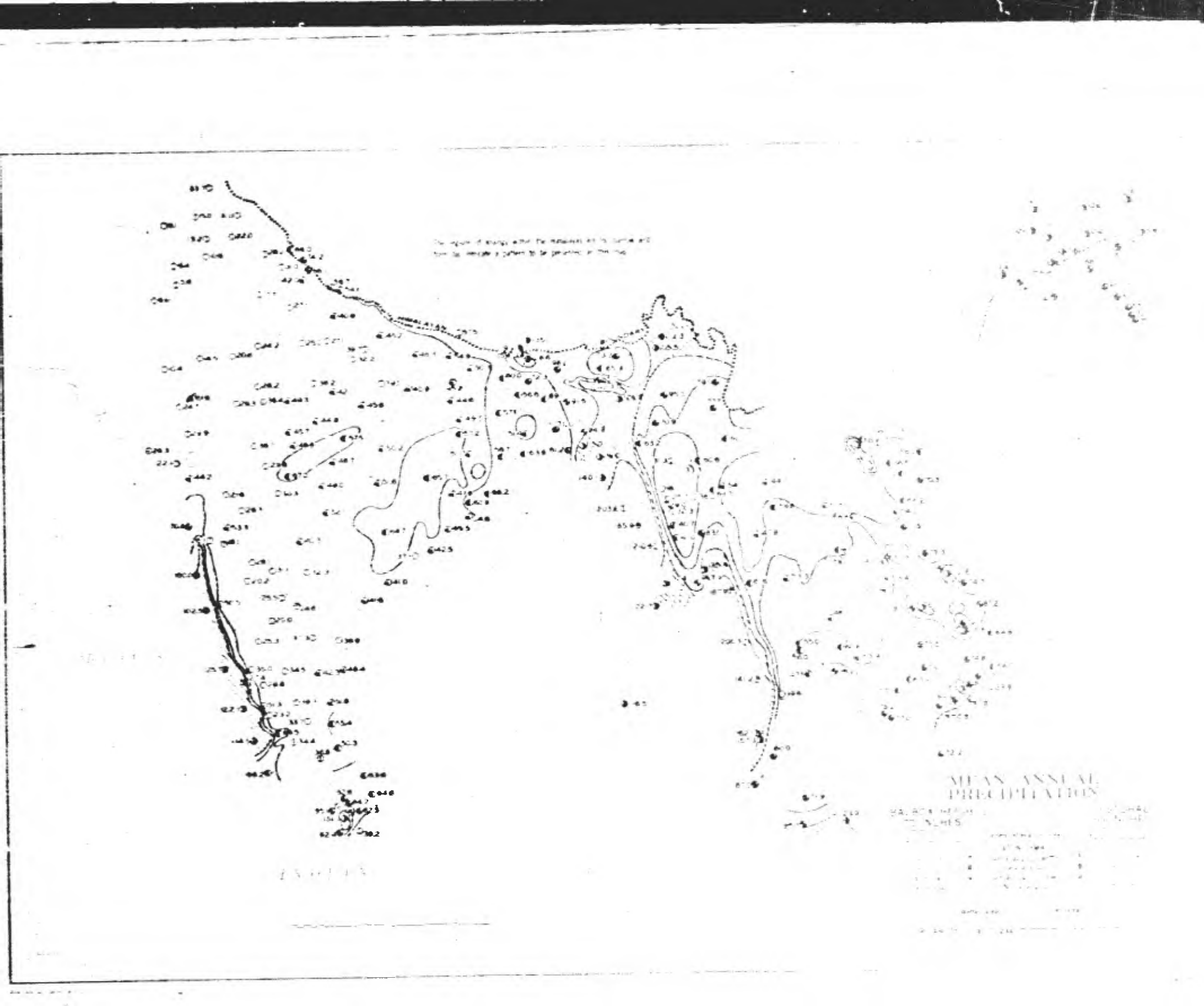
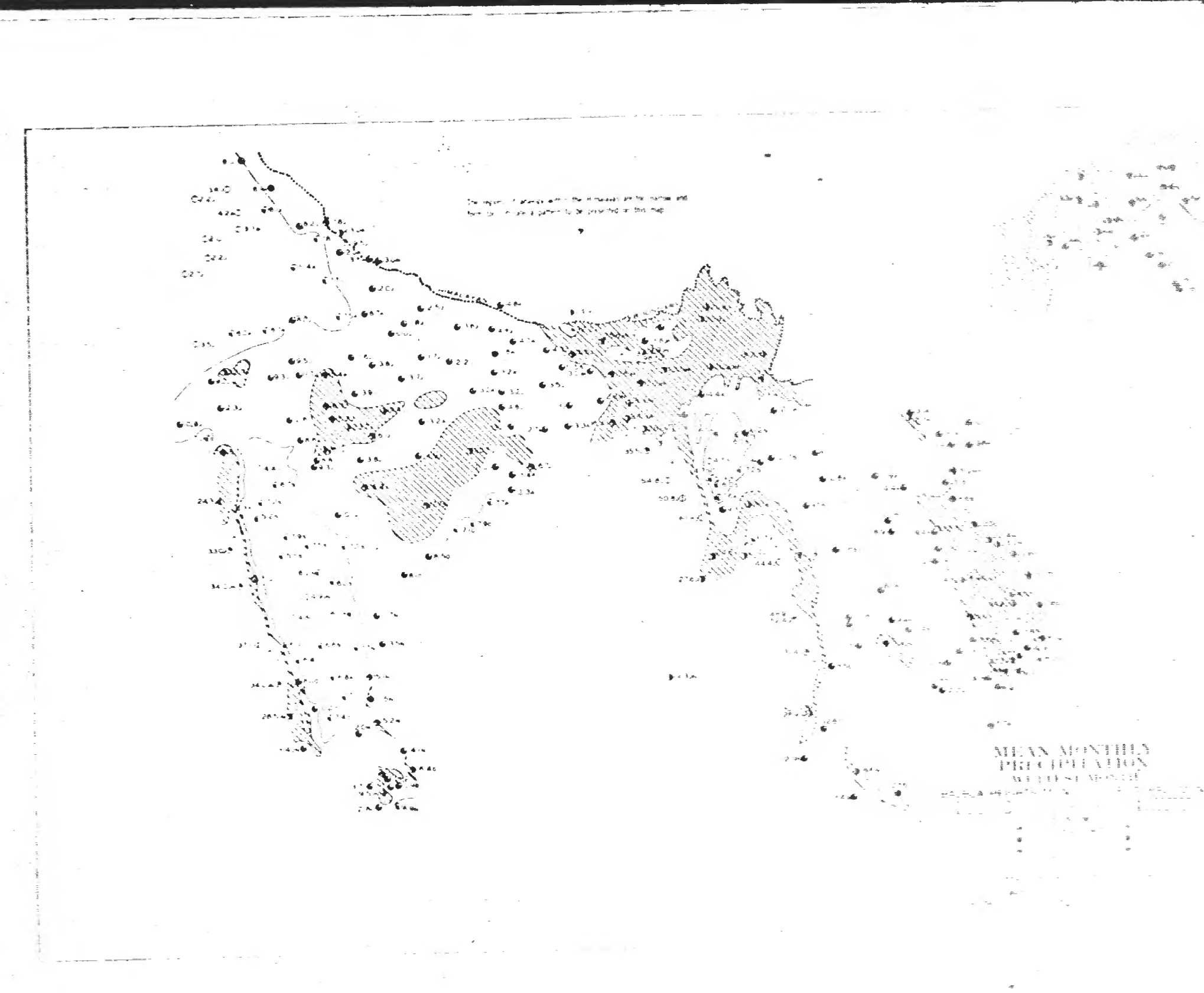

MEAN DAILY MAXIMUM
TEMPERATURE
WARMEST MONTH
BALBOA HEIGHTS 90°F

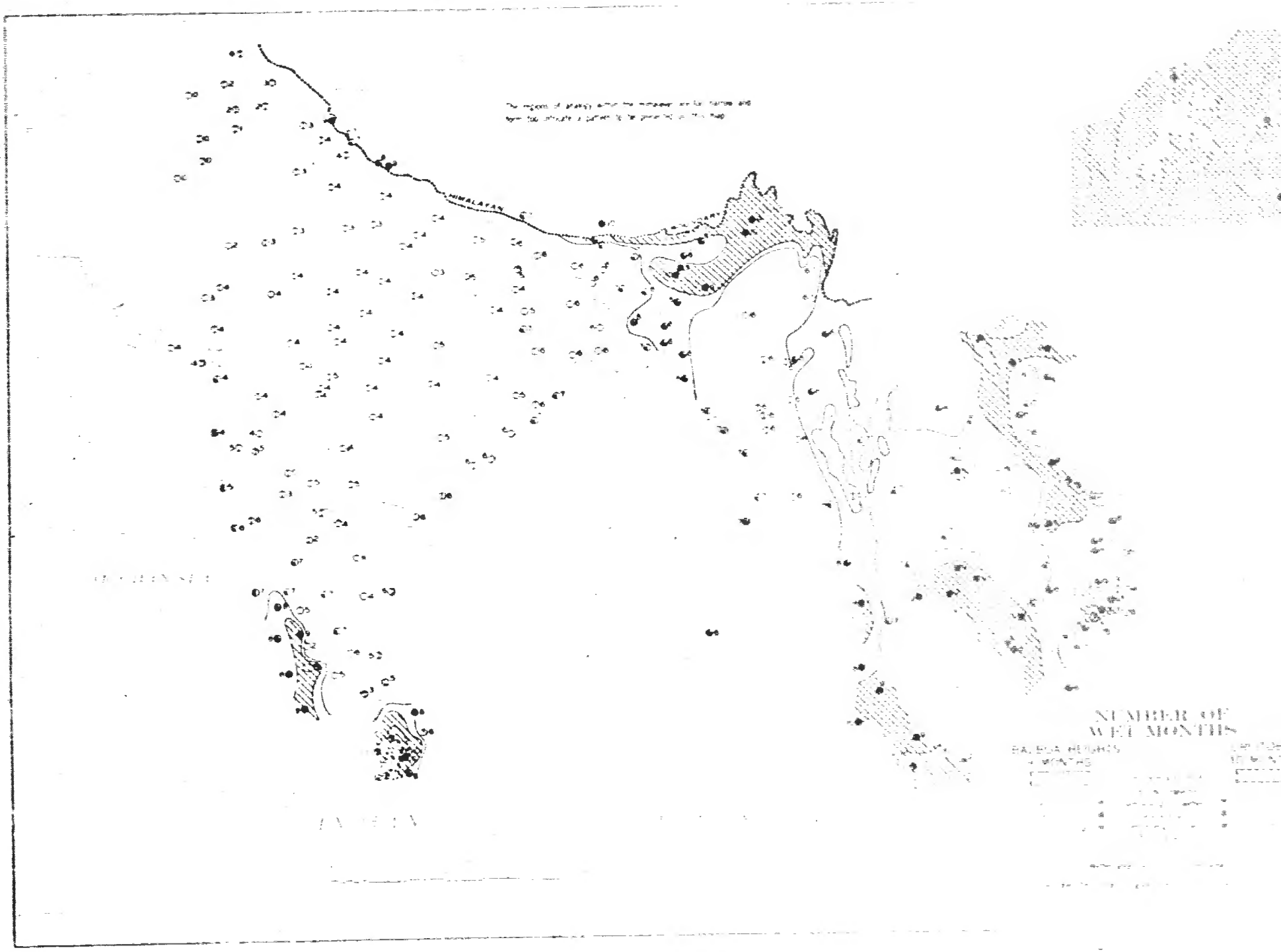

MEAN TEMPERATURE
COLDEST MONTH

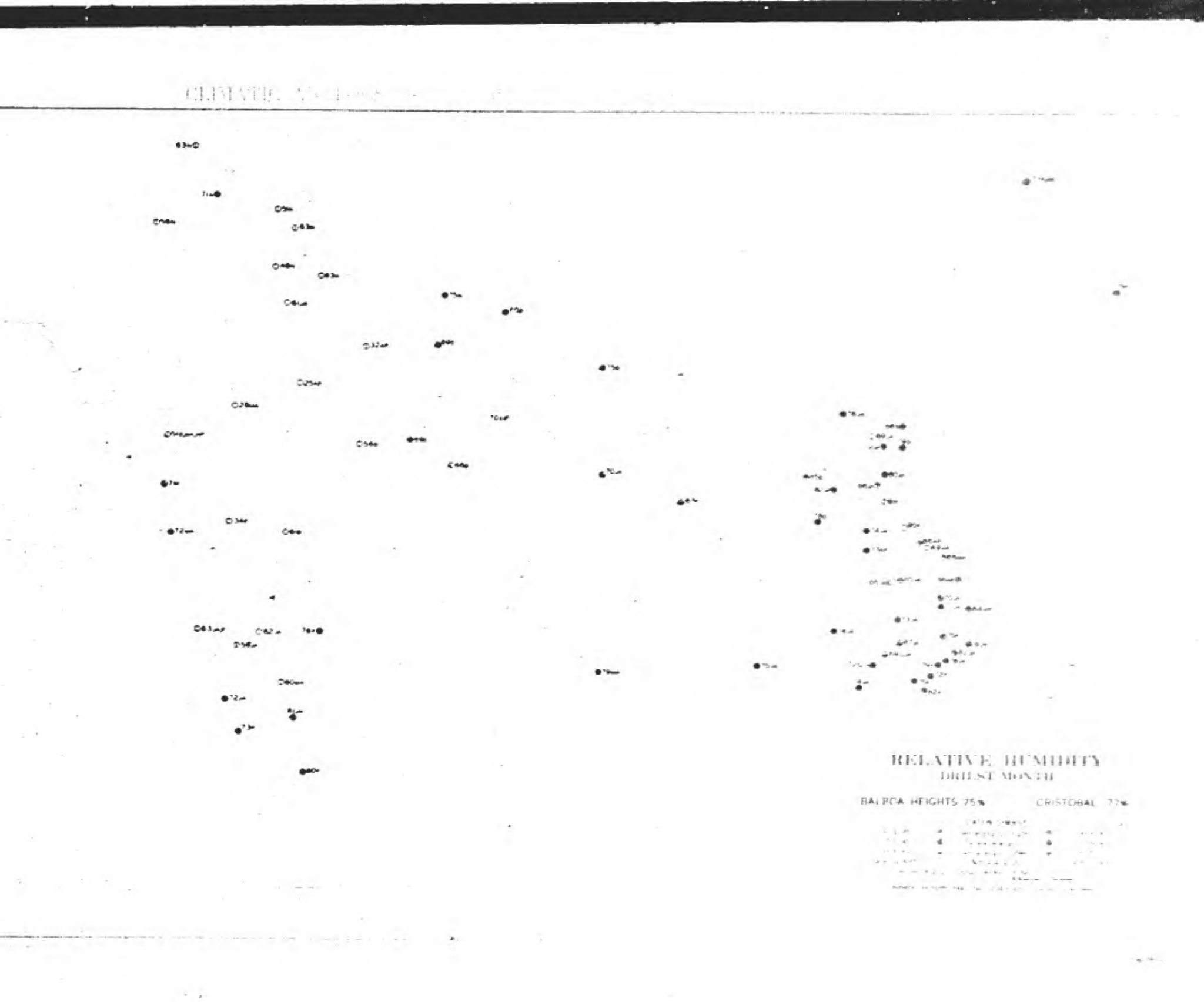

MEAN DAILY MINIMUM
TEMPERATURE




MEAN ANNUAL
PRECIPITATION

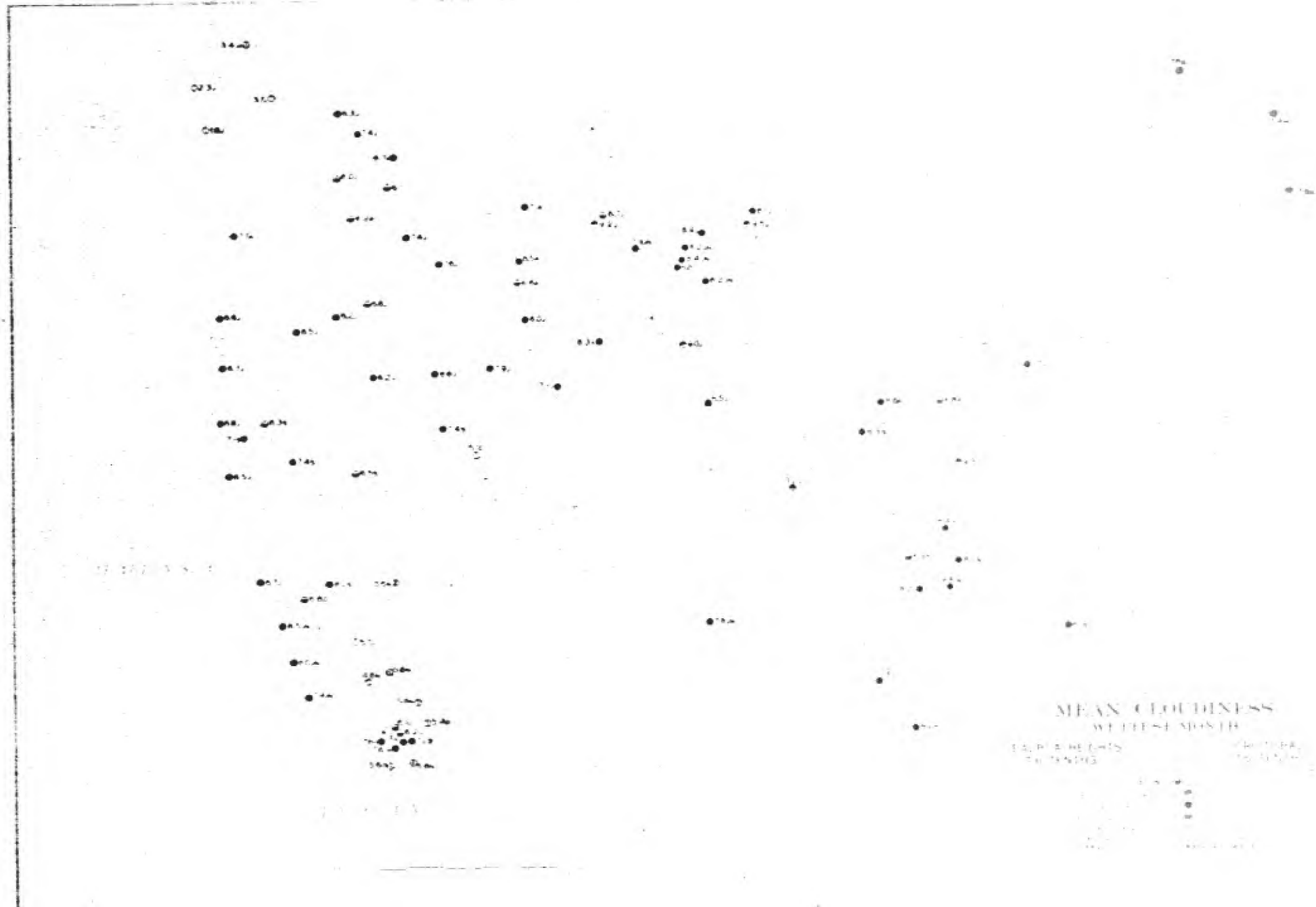


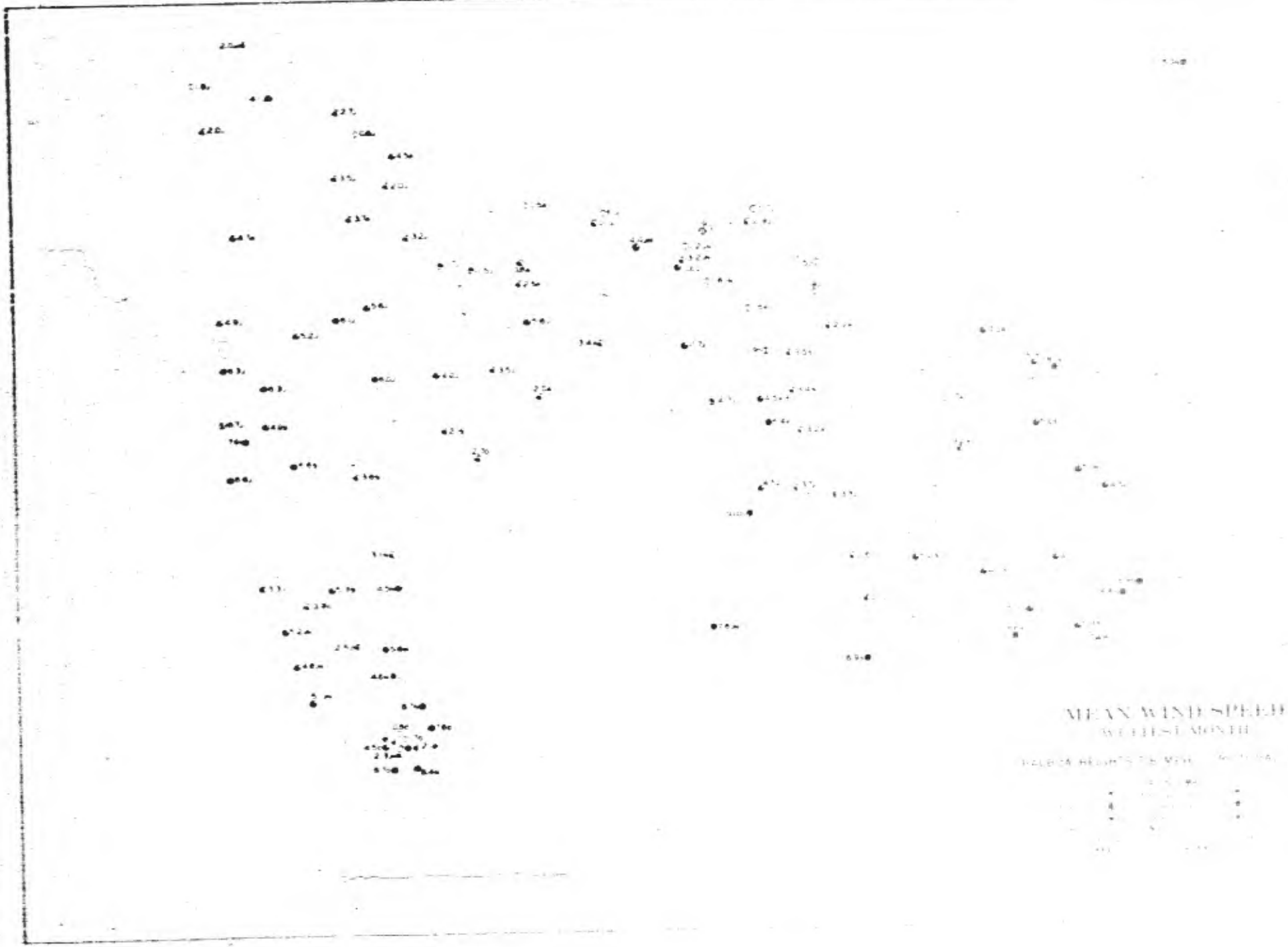

HIMALAYAN



RELATIVE HUMIDITY
DRIEST MONTH

BALBOA HEIGHTS 75% CRISTOBAL 77%


MEAN CLOUDINESS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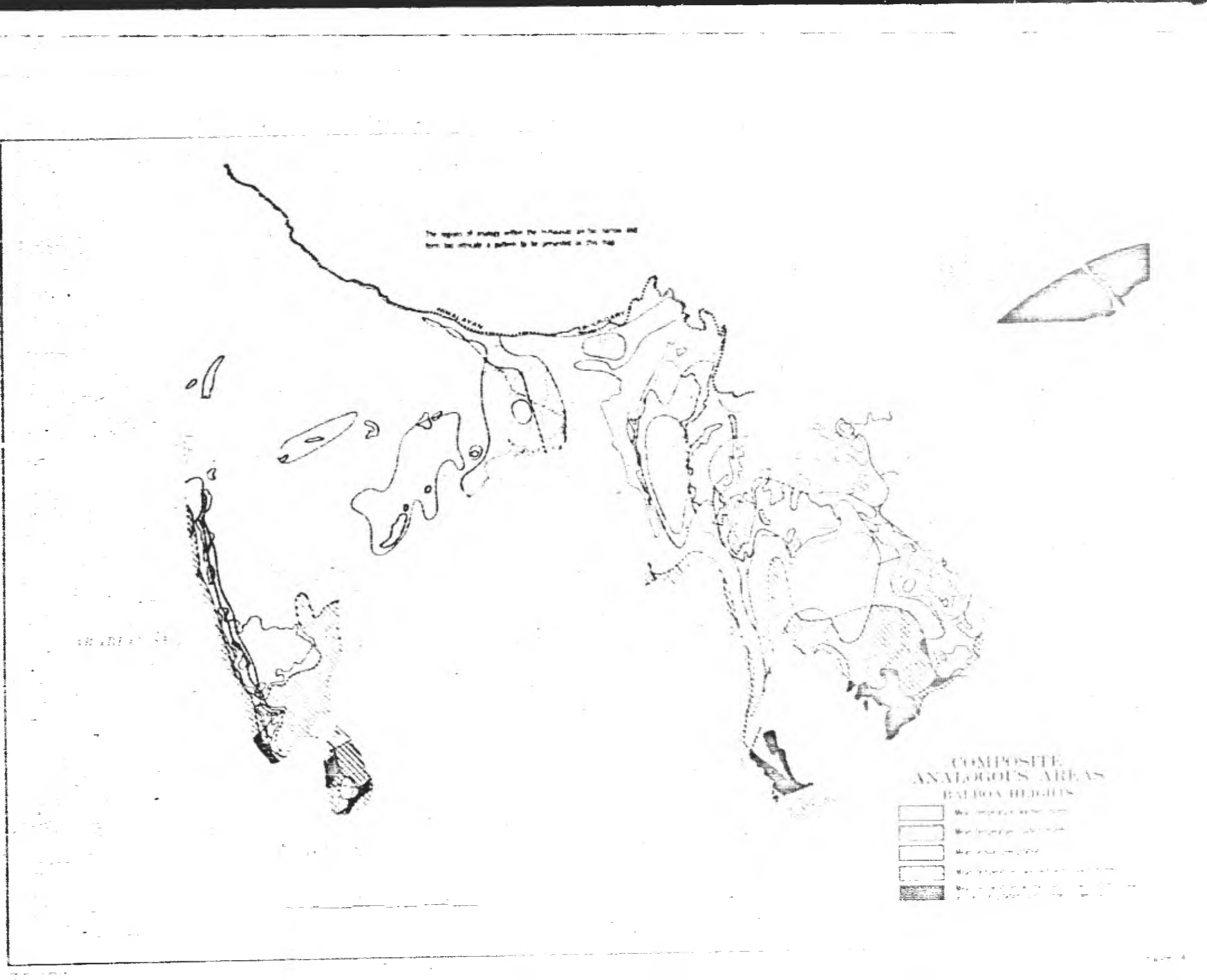
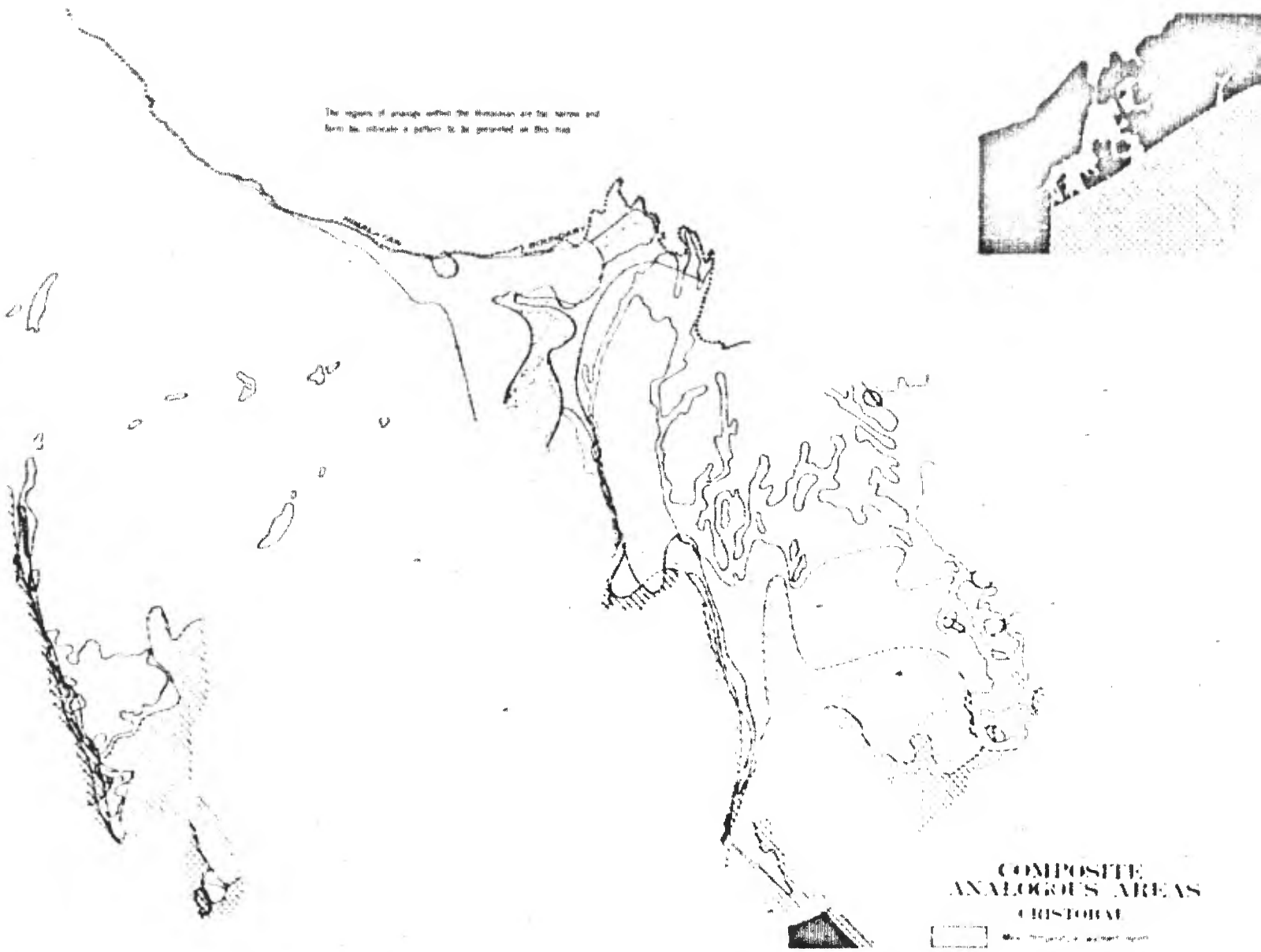

COMPOSITE
ANALOGOUS AREAS
BALBOA HEIGHTS


COMPOSITE
ANALOGOUS AREAS
CRISTOBAL